Using SLEUTH Land Cover Predictions to Estimate Changes in Runoff Quality and Quantity in the Delmarva Peninsula

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Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Science
in
Civil Engineering

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April 18, 2011
Manassas, Virginia

Keywords: Water Quality, Water Quantity, Chesapeake Bay, SLEUTH, Land Cover.

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ABSTRACT

Anticipating future trends in land development and climate change is a constant challenge for engineers and planners who wish to effectively compensate for the resulting changes in stormwater runoff that will inevitably follow. This study is a regional attempt at predicting how predicted changes in land cover will affect runoff characteristics in a number of watersheds throughout the Delmarva Peninsula when compared to the current state. To predict changes in land cover and the associated land use, the SLEUTH model coupled with PED utilized a number of different inputs including population growth trends, existing geography, current land planning policies as well as different growth factors to predict where urban growth is most likely to occur. The model creates maps which show the approximate location of predicted growth for the year 2030.

Using SLEUTH output, the magnitude of changes that can occur in runoff quality and quantity due to land cover changes were estimated in each of the seventeen representative watersheds that were chosen within the Delmarva Peninsula. Changes in water quality were calculated based on nutrient loading rates for sediment, phosphorus, and nitrogen. These nutrient loading rates correspond to different land uses within different county segments in the peninsula. The expected changes in water quantity were quantified using the United States Department of Agriculture's Natural Resources Conservation Services' TR-20 which estimated the peak flows for each watershed based on watershed's size, land cover, soils, and slope.

Evaluating the magnitude of these potential changes in the Delmarva Peninsula provides an important look into the effects of increased urban development on the predominantly agrarian land mass, the majority of which drains to the Chesapeake Bay.

Acknowledgements

There are many people to thank for putting up with me through the years and helping me along my path. First, of course, my family has been my rock throughout my entire life, supporting me emotionally and financially from day one as well as supporting me through the last phases of writing my thesis. My parents and my sister are some of the best friends I have.

Thank you to both Dr. Claire Jantz at Shippensburg University and Jim Reilly for their work with the SLEUTH and PED models. Obviously, my work wouldn’t be possible without the time and hard work spent in creating the SLEUTH output.

I also consider it very lucky that I find myself studying at Virginia Tech with a number of very accomplished staff and faculty. Special thanks to Dr. Moglen, who has made it possible for me to work on a project in my preferred area of study and enjoy the work every step of the way. Dr. Moglen has been a very helpful and knowledgeable advisor and I want to acknowledge the time he has spent answering my plentiful questions and helping me through my studies.

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List of Abbreviations

AOI- Area of interest
Boh- Bohemia River Watershed
CBPO- Chesapeake Bay Program Office
CBPOLU- Chesapeake Bay Program Office Land Use
C-CAP- Coastal Change Analysis Program
CN- Curve number
Cosegments- Chesapeake Bay Program Office County Segments
COV- Coefficient of Variation
HS- Headship
HSPF- Hydrological Simulations Program-Fortran
N-Nitrogen
NLCD- National Land Cover Dataset
NOAA- National Oceanic and Atmospheric Administration
P- Phosphorus
PED-Population and Employment Distribution Model
SLEUTH- Slope, Land Use, Exclusion, Urban Extent, Transportation, Hillshade Model
TrdA- Tred Avon River Watershed
Trp- Trappe Creek Watershed
TS- Total sediment
Wic- Wicomico River Watershed
WSM- Watershed model

Chapter 1: Introduction

1.1 Background

With changing climate and increased pressure on the environment from population growth and urban sprawl, planners and scientists need to find ways to predict and prepare for these impending changes. The first challenge is to model and predict how and where urbanization will occur based on the existing land cover and planning trends. These predictions can then be used to quantify the resulting effects that this will have on stormwater runoff quality and quantity. Increases in urbanization and development can generate higher nutrient loads and stormwater runoff peaks with the potential to cause damage to existing waterways, increase sedimentation and erosion, and decrease water quality. However, proper mitigation and preventative planning can reduce these detrimental effects and ideally recreate a more natural hydrologic state.

This study will use predicted changes in land cover to assess the effects that these changes will have on stormwater quality and quantity for a number of given areas or catchments in the Delmarva Peninsula. To do this, land cover scenarios were obtained from a prediction model called SLEUTH (USGS 2003) whose name reflects the following inputs which are used to run the model: slope, land use, exclusion, urban extent, transportation and hillshade. SLEUTH was coupled with input from a population and employment distribution model (PED) (Reilly 1997a; 1997b) which created a predicted growth footprint based on linear, high, and low growth scenarios. Using output from the PED, SLEUTH created spatial data showing predictions of future land cover in the year 2030 for three different planning scenarios: a current trends scenario, a planning scenario, and a resource scarcity/climate change scenario. These scenario combinations were selected so a comparative study could be done evaluating a range of essentially the worst-case to best-case scenarios of land cover change and their effects.

Land cover predictions were generated by James Reilly (Reilly 1997b), using PED, and Dr. Claire Jantz (Jantz et al. 2004), using SLEUTH coupled with PED output. Based on these data, nutrient loads, including total sediment (TS), Phosphorus (P), and Nitrogen (N) will be estimated. Peak flow increases can also be estimated and compared to existing conditions.

Together, these results can serve to guide future development or at least give insight on what can be expected under each of the three planning scenarios.

1.2 Problem Statement

The Delmarva Peninsula is a peninsula on the East Coast of the United States including Delaware and parts of Virginia and Maryland, as shown in Figure 1. This peninsula possesses the unique quality of an area that has yet to experience heavy urbanization while having a large amount of agricultural land in close proximity to a number of larger cities. This creates the potential for major development and increases in imperviousness in future land cover. Another characteristic to note is that approximately 60 percent of the peninsula drains to the Chesapeake Bay. This is important because the Chesapeake Bay is in specific need of remediation from the historically high amounts of nutrient laden runoff deposited in the bay and anoxic conditions that still exist in parts of the bay (Kemp et al. 2005). As the United States' largest estuary, the Chesapeake Bay is the focus of many restoration efforts due to increasing indicators of its ailing health. Determining the magnitude of future changes in runoff behavior will be critical in making informed decisions on current and future planning strategies.

For an area like the Delmarva Peninsula, a thorough study and analysis of future development can guide decisions on land planning policies and regulations. To understand the results of these different strategies, separate predictions will be made based on current development trends and based on smart or low impact development. A resource scarcity scenario will also be studied which includes low impact development as well as predicted sea level rise from climate change. Since the Chesapeake Bay watershed is particularly sensitive to the effects of climate change, sea level rise should be considered (Najjar et al. 2010). Changes in associated runoff volume and nutrient loadings can be compared to illustrate the magnitude of the differences between each of the scenarios.

SLEUTH attempts to spatially model the location of future development; however this is a complicated and difficult task. Since the output is a GIS raster, each land cover layer must assign land cover predictions to exact cells in the raster. There is virtually no way to predict the exact location of land cover/use changes with total accuracy since it is driven by social, economic, political, and environmental factors. To account for the variability, there are 10 different realizations for each planning scenario. The exact locations of predicted land cover are spatially different on each realization, but the rules used to create them are the same and the overall amount of land cover type varies little.

To understand the changes that will affect the Delmarva Peninsula and the downstream water bodies, changes in both water quality and quantity have to be understood and quantified so that the effect of these changes will be expected and properly mitigated or prevented if necessary.

1.3 Goals

The goals of this study are:

1) To develop a method, using GIS and output from the SLEUTH model, which can estimate increases in nutrient loads and peak flow for a given area in the Delmarva Peninsula. The model results will contain nutrient load and peak flow estimates based on each of the three different land use scenarios, which will be analyzed relative to one another to compare the effects of land use planning and climate changes in contrast to the current trends model .
2) To quantify the uncertainty and variations associated with the model and the inputs to the model. A major source of error that must be understood is how the accuracy of the SLEUTH predictions change when the size of the analysis area changes. This error will be quantified using trial areas that range in size.
3) To quantify the variation between the different realizations which SLEUTH creates for each land use scenario which will also be statistically analyzed.
4) To quantify the change in amount of variation between SLEUTH realizations for study areas of varying size.

1.4 Summary

Understanding the predicted changes in water quality and quantity and how they vary will provide insight into the future state of the Delmarva Peninsula's natural resources and how governing bodies can prepare for these changes. It should also provide insight into how the different scenarios for growth, management, and climate change can exacerbate conditions.

Chapter 2: Literature review

The overall model used in the study uses output from the Population and Employment Distribution model to guide the SLEUTH model's prediction of land cover changes within the Delmarva Peninsula. These predictions are converted from one land cover categorization system into two more so that values from the Chesapeake Bay Program Office's watershed model can be used quantify changes in runoff quality.

Below is an overview of the major components in this study and peer-reviewed evaluations of these components. The SLEUTH model is a relatively recent adaptation of a cellular automaton model which has been found to supply reasonable urban growth results despite some criticism of the modeling methods. PED is being coupled with SLEUTH for the first time in this study providing valuable input into local population growth patterns. Loading rates from the Chesapeake Bay Program Office were used to calculate nutrient loads; however the method used to determine loading rates has been questioned. Finally, the origins and background for each land cover/land use classification system are described to provide and understanding of how they relate to one another.

2.1 SLEUTH documentation

The SLEUTH model, consisting of a growth model coupled with a land-cover-change model, is used to predict the location and quantity of urban/ developed land cover change based on historical growth trends (Clarke et al. 1997; USGS 2003). SLEUTH is a raster-based cellular automaton model which applies a set of rules and growth parameters to the assigned base condition. (USGS 2003). The model requires the following inputs, which also provide the naming acronym:, slope, land use, exclusion, urban extent, transportation and hillshade. Using these data, SLEUTH repetitively applies five growth rules or factors, which the user must calibrate for his or her specific study area based on historical data, over a set time increment (typically one year) until the desired end point is reached. Defining and calibrating these growth factors results in the creation of four major growth types. Both these growth types and user-calibrated growth factors are summarized in Table 1.

Table 1. A Summary of the Growth Processes used in SLEUTH (Jantz et al. 2004)

Growth Factor	Growth Type	Description
diffusion	spontaneous	Growing new developed cells in spontaneous or dispersed areas that are suitable for development
breed	new spreading center	Adding growth onto cells that were grown spontaneously through diffusion
spread	edge growth	Growth on the edges of growth centers (existing or new)
slope resistance	(affects all types)	Can deter growth from steeper gradients
road-gravity	road influenced	Growth occurring along transportation networks, encouraged due to the road-gravity factor

SLEUTH also has another group of growth rules for “self-modification” where the growth rate and growth parameters can be adjusted if growth rates become too high or low and hit defined thresholds as the model is iterating from the initial condition to the final prediction output (Clarke et al. 1997; Clarke and Gaydos 1998; USGS 2003). By applying the five growth rules as well as the self-modifying rules, “emergent” behavior evolves that is intrinsically more complex than if the initial five growth rules were applied on their own. (Clarke and Gaydos 1998) Complete documentation may be found at the Project Gigalopolis website (USGS 2003)

2.1.1 Previous uses of the SLEUTH model

Many methods have been used to predict urban growth due to the increasing need to model the effects of land use changes. Some earlier studies simply used a cellular automaton model to simulate urban growth patterns and densities (Yeh and Li 2001; 2002). In one of the earliest studies to use SLEUTH, Clarke and Gaydos (1998) modeled large urban areas such as San Francisco and the Washington/Baltimore area and concluded that SLEUTH’s approach “can produce useful results”. Herold et al. (2003) applied SLEUTH to Santa Barbara, CA and found it useful in modeling the amount as well as spatial location of development in 2030. The SLEUTH model has also been used internationally, including a study of northeastern China (Wu et al. 2009) and modeling growth in Mashad, Iran where there have been high levels of population growth (Rafiee et al. 2009).

Rafiee et al. (2009) concluded that although SLEUTH’s result may not be completely accurate, they provide meaningful comparisons of the outcomes of different planning strategies. The idea of using SLEUTH to examine how predicted growth varies using different scenarios was also exercised by Jantz et al. (2004) in a study of the Baltimore-Washington metropolitan area where three different scenarios were examined: Current trends, managed growth, and ecologically sustainable growth. Their 2004 study in particular sets the ground work for the scenarios that are addressed in this study and shows how the results can effectively show a range of impacts of the different planning strategies.

In a more recent study, Jantz et al. (2010) modified SLEUTH to incorporate more social and economic factors and to obtain more accurate results. The study area included the entire Chesapeake Bay Watershed and separated the watershed into smaller divisions to categorize development density. As an added input, the study added areas that were attractive for development, as opposed to just including areas that are excluded from development (Jantz et al. 2010). This is one of the largest scale applications for SLEUTH to date.

2.1.2 Strengths and shortcomings of the SLEUTH model

As previously mentioned, the SLEUTH model has been cited by a number of researchers for its ability to create reasonable and informative predictions of the patterns, density, and/or quantity of future urban development (Herold et al. 2003; Wu et al. 2009). Cellular automata models have been noted to consistently and repeatedly be able to mimic development patterns through calibration with historical data (Yeh and Li 2002; Jantz et al. 2004). SLEUTH has the ability to apply a number of individual processes and rules that interact and aggregate throughout the model’s application. Such complexity in forces is similar to the complicated and interlinked reasons that can inspire land development in the real world (Clarke and Gaydos 1998; Torrens and O'Sullivan 2001). As a reliable method of land cover prediction, SLEUTH is vital in providing the necessary information to planners and policymakers who need to understand what land use changes can reasonably be expected (Torrens and O'Sullivan 2001; Yeh and Li 2001; Herold et al. 2003).

There are also a number of flaws in the SLEUTH model, some of which maybe unavoidable. Ideally, a model of land use change would include a way to include all of the factors that can cause or influence the amount and location of urban growth. The major causes for development usually include economic, environmental, technological and social processes as well as evolving urban spatial structure. SLEUTH does not incorporate any way to model economic forces (Herold et al. 2003) or social factors which are nonspatial (Yeh and Li 2002).
Torrens and O’Sullivan (2001) argue that the simplicity of using individual processes that interact to create larger processes, while remaining one of a cellular automata’s strengths, also prevents SLEUTH from representing “real-world phenomena” due to the model’s abstractness. Yeh and Li (2002) argue that it is a major oversight in current cellular automata models that development density, population density and property values variations are not modeled within highly urban areas. Although there are still a number of more microeconomic and social real-world processes which SLEUTH does not capture (Jantz et al. 2004), Torrens and O’Sullivan argue that these small-scale processes create larger patterns which a cellular automaton, such as SLEUTH, can model (2001) .

Another important characteristic of SLEUTH is that its performance varies with space as well as development rates. Differences between SLEUTH predictions when compared to historical remote sensing data are largest when the spatial urban growth pattern is changing rapidly (Herold et al. 2003). A number of studies have also found evidence that SLEUTH’s accuracy increases at coarser or more regional scales (Jantz et al. 2004; Wu et al. 2009). The results of a spatial accuracy assessment revealed some of the limitations of the model in simulating local patterns of urban development and show that the model works well at a scale of the 11-digit hydrologic unit code (HUC) watersheds as well as at the county-level (Jantz et al. 2004).

SLEUTH can successfully provide insight into the magnitude of land cover change as well as the impacts of alternative scenarios (Jantz et al. 2004).

2.2 Population and Employment Distribution Model (PED)

The New Jersey Office of State Planning's Population and Employment Distribution (PED) model (Reilly 1997a; 1997b) was coupled with SLEUTH to provide SLEUTH with amounts of expected development based on population and employment rates. PED uses predicted population and employment growth in minor civil divisions and determines a subsequent urbanization footprint required to accommodate such growth, which may be used as input into the SLEUTH model. By including variables such as headship rates, or the amount of households per person, and land availability within minor civil divisions, PED promotes a more accurate depiction of growth patterns at a more local level.

2.3 Land cover/ land use

To use the SLEUTH output in conjunction with the Chesapeake Bay Program Office method for calculating nutrient loads, three different land cover classification systems had to be used: the National Land Cover Dataset (NLCD) (Homer et al. 2007), Chesapeake Bay Program Office (CBPO) (Hopkins et al. 2000) and NOAA's Coastal Change Analysis Program (C-CAP) (NOAA Coastal Services Center 2009). All three methods are based on the Anderson method of organizing land cover (Anderson et al. 1976).

2.3.1 National Land Cover Dataset (NLCD)

The National Land Cover Dataset (NLCD) was developed by the MultiResolution Land Characteristics (MRLC) Consortium (http://www.mrlc.gov/) to satisfy the need for a nationally consistent land cover raster (Homer et al. 2007). The 30-meter NLCD satisfies the need for continuous and "seamless" land cover data at an intermediate scale (Vogelmann et al. 2001). The 2001 version of NLCD has some unavoidable inaccuracies in land cover determination from the original remotely sensed imagery, but its accuracy has increased relative to previous versions thanks to improved technological and methodological advances. This classification method remains one of the most widely used for larger applications (Vogelmann et al. 2001; Wickham et al. 2010).

2.3.2 Coastal Change Analysis Program (C-CAP)

The land cover predictions created by SLEUTH in this study are categorized using NOAA's Coastal Change Analysis Program (NOAA Coastal Services Center 2009), a system developed for use in coastal applications of the NLCD and gives particular emphasis to wetlands. The first C-CAP land cover data set available is for1992 and has been used since in a number of coastal applications by NOAA for analyzing land cover change and potential for erosion or pollution throughout the east and southern coasts of the US including Hawaii. (NOAA Coastal Services Center 2009)

Full documentation for methods and a description of the C-CAP land cover system can be found in NOAA's guide for implementation (NOAA 1995).

2.3.3 Chesapeake Bay Program Office (CBPO)

The Chesapeake Bay Program Office land cover system is a combination of EPA Environmental Monitoring and Assessment Program (EMAP) (US EPA 1994), NOAA Coastal Change Assessment Program (NOAA 1995), and the USGS Geographic Information Retrieval and Analysis System (GIRAS) databases (Mitchell et al. 1977) land cover sets (Hopkins et al. 2000). To estimate nutrient loads, CBPO land cover must be converted to CBPO land use according to CBPO's predetermined formulas, except in case of agricultural land use, where land use is based on the percentage of existing land uses within each individual county according to US Agricultural Census data (Hopkins et al. 2000).

2.3 Chesapeake Bay Program Office (CBPO) Model

The Chesapeake Bay Watershed Model (WSM) was created by the Chesapeake Bay Program (http://www.chesapeakebay.net) in 1982 to help guide efforts to improve the water quality in the Chesapeake Bay. The model divides the Chesapeake Bay watershed into model segments based on soil properties, model calibration station locations, terrain, model running time as well as other pertinent data. The model segments were then overlaid with county and state borders to create what the CBPO calls "county segments" or "cosegments" (Hopkins et al. 2000). Finally, edge-of-stream nutrient loading rates were developed using the US EPA's Hydrological Simulation Program-Fortran (HSPF) (Bicknell et al. 1993) which modeled the entire watershed.

Despite this tool's established and repeated use by the CBPO, there is a noteworthy flaw with the method used to determine the nutrient loading rates. Shivers and Moglen (2008) report that the tool uses "spurious" correlation to estimate nutrient loadings and thus the loads may be exaggerated and inaccurately derived. When comparing the model's calculated nutrient loads with collected data, it was found that the CBPO watershed model (WSM) does an acceptable job of modeling nitrogen, a subpar estimation or phosphorus loads and varies in its accuracy for sediment prediction from poor to acceptable (Shivers and Moglen 2008). This flaw in the model does not negate all results, but it should draw attention to the potential unreliability of these results as absolute loading values.

2.4 Overview

Describing some of the strengths, weaknesses, and previous uses of cellular automata, PED, and the CBPO models provides a background for understanding the nature and reliability of the output. There has been previous criticism of both cellular automata and the CBPO models, however both provide reasonable estimations of the desired output which is useful in quantifying how the changes in these output from 2005 to the predicted state in 2030. By adding input from PED, some of the economic aspects of urban growth, such as employment modeling, will be incorporated into SLEUTH, addressing one of its cited weaknesses.

The explanations of each land cover/land use system establish that each system is based on Anderson land cover categories and derived from remote sensor data. The categories described in each classification system vary, but reasonable rules to interchange categories as necessary for the analysis have been developed. The exact conversions between land cover systems as well as model implementation is described in more details in the methods section of Chapter 3.

Chapter 3: Analysis of Select Watersheds in the Delmarva Peninsula for changes in Runoff Quality and Quantity based on SLEUTH Land Cover Model Predictions

3.1 Abstract

Anticipating future trends in land development and climate change is a constant challenge for engineers and planners who wish to effectively compensate for the resulting changes in stormwater runoff that will inevitably follow. This study is a regional attempt at predicting how changes in land cover will affect runoff characteristics in a number of watersheds throughout the Delmarva Peninsula when compared to the current state. To predict changes in land cover and the associated land use, the SLEUTH model coupled with PED utilizes a number of different inputs including population growth trends, existing geography, current land planning policies as well as different growth factors to predict where urban growth is most likely to occur. The model creates maps showing the location of predicted growth for the year 2030.

Using SLEUTH output, the magnitude of changes that can occur in runoff quality and quantity due to land cover changes were estimated in each of the seventeen representative watersheds that were chosen within the Delmarva Peninsula. Changes in water quality were calculated based on nutrient loading rates for sediment, phosphorus, and nitrogen. These nutrient loading rates correspond to different land uses within different county segments in the peninsula. The expected changes in water quantity were quantified using the United States Department of Agriculture's Natural Resources Conservation Services' TR-20 which estimated the peak flows for each watershed based on watershed's size, land cover, soils, and slope.

Evaluating the magnitude of these potential changes in the Delmarva Peninsula provides an important look into the effects of increased urban development on the predominantly agrarian land mass, the majority of which drains to the Chesapeake Bay.

3.2 Introduction

With changing climate and increased pressure on the environment from population growth and urban sprawl, planners and scientists need to find ways to predict and prepare for these impending changes. The first challenge is to model and predict how and where urbanization will occur based on the existing land cover and planning trends. These predictions can then be used to quantify the resulting effects that this will have on stormwater runoff quality and quantity. Increases in urbanization and development can generate higher nutrient loads and stormwater runoff peaks with the potential to cause damage to existing waterways, increase sedimentation and erosion, and decrease water quality. However, proper mitigation and preventative planning can reduce these detrimental effects and ideally recreate a more natural hydrologic state.

This study will use predicted changes in land cover to assess the effects on stormwater quality and quantity for a number of given areas or catchments in the Delmarva Peninsula. To accomplish this, land cover scenarios were obtained from a prediction model called SLEUTH (USGS 2003) whose name is an acronym reflecting the following model inputs: slope, land use, exclusion, urban extent, transportation and hillshade. SLEUTH was coupled with input from a population and employment distribution module (PED) (Reilly 1997a; 1997b) which created a predicted growth footprint based on linear, high, and low growth scenarios. Using output from PED, SLEUTH created spatial data showing predictions of future land cover in the year 2030 for three different planning scenarios: a current trends scenario, a planning scenario, and a resource scarcity/climate change scenario. These scenario combinations were selected so that a comparative study could be conducted evaluating a range of essentially worst-case to best-case scenarios of land cover change and its effects.

Land cover predictions were generated by Reilly (1997b), using PED, and Jantz (2004), using SLEUTH coupled with PED output. Based on these data, nutrient loads, including total sediment (TS), Phosphorus (P), and Nitrogen (N) will be estimated. Peak flow increases can also be estimated and compared to existing conditions. Together, these results can serve to guide future development or at least give insight on what can be expected under each of the three planning scenarios.

The Delmarva Peninsula is a peninsula on the East Coast of the United States including Delaware and parts of Virginia and Maryland, as shown in Figure 1. This peninsula possesses the unique quality of an area that has yet to experience heavy urbanization while having a large amount of agricultural land in close proximity to a number of larger cities. This creates the potential for major development and increases in imperviousness in future land cover. Another characteristic to note is that approximately 60 percent of the peninsula drains to the Chesapeake Bay. This is important because the Chesapeake Bay is in specific need of remediation from the historically high amounts of nutrient laden runoff deposited in the bay and anoxic conditions that still exist in parts of the bay (Kemp et al. 2005). As the United States' largest estuary, the Chesapeake Bay is the focus of many restoration efforts due to increasing indicators of its ailing health. Determining the magnitude of future changes in runoff behavior will be critical in making informed decisions on current and future planning strategies.

For an area like the Delmarva Peninsula, a thorough study and analysis of future development can guide decisions on land planning policies and regulations. To understand the results of these different strategies, separate predictions will be made based on current development trends as well as smart or low impact development. A resource scarcity scenario will also be studied which includes low impact development as well as predicted sea level rise from climate change. Since the Chesapeake Bay watershed is particularly sensitive to changes in sea level (Yin et al. 2009) , sea level rise should be considered in combination with land cover changes, as it can compound hydrological changes (Hejazi and Moglen 2008; Najjar et al. 2010). It has been predicted that the global mean sea level will rise by 0.6 to 2 feet in the next century (IPCC 2007) inundating wetlands and coastal areas and endangering local flora and fauna (Barbosa and Silva 2009).Changes in associated runoff volume and nutrient loadings can be compared to illustrate the magnitude of the differences between each of the scenarios.

SLEUTH attempts to model the location of future development; however this is a complicated and difficult task. Since the output is a GIS raster, each land cover layer must assign land cover predictions to exact cells in the raster. There is virtually no way to predict the exact location of land cover/use changes with total accuracy since it is driven by social, economic, political, and environmental factors. To account for the variability, there are 10 different realizations for each planning scenario. The exact locations of predicted land cover are spatially different on each realization, but the rules used to create them are the same and the overall amount of land cover type varies little.

To understand the changes that will affect the Delmarva Peninsula and the downstream water bodies, changes in both water quality and quantity have to be understood and quantified so that the effect of these changes will be expected and properly mitigated or prevented if necessary.

3.3 Background

The model used in the study uses output from the Population and Employment Distribution (PED) model (Reilly 1997b) to guide the SLEUTH model's prediction of land cover changes within the Delmarva Peninsula. These predictions are converted from the native land cover categorization system to values from the Chesapeake Bay Program Office's watershed model so that changes in runoff quality can be quantified.

The SLEUTH model is a relatively recent adaptation of a cellular automaton model which has been found to supply reasonable urban growth results. The PED model is coupled with SLEUTH for the first time in this study providing valuable input into local population growth patterns. The Chesapeake Bay Program Office Model was used to calculate nutrient loads based on the loading rates determined by the US EPA Chesapeake Bay program.

The SLEUTH model is used to predict the location and quantity of developed land cover change based on historical growth trends (Clarke et al. 1997; USGS 2003). SLEUTH is a raster-based cellular automaton model which applies a set of rules and growth parameters to the assigned base condition (USGS 2003). SLEUTH repetitively applies five growth rules or factors, which the user must calibrate for his or her specific study area based on historical data, over a set time increment (typically one year) until the desired ending point is reached. Defining and calibrating these growth factors results in the creation of four major growth types. Both these growth types and user-calibrated growth factors are summarized in Table 2.

Table 2. A Summary of the Growth Processes used in SLEUTH (Jantz et al. 2004)

Growth Factor	Growth Type	Description
diffusion	spontaneous	Growing new developed cells in spontaneous or dispersed areas that are suitable for development
breed	new spreading center	Adding growth onto cells that were grown spontaneously through diffusion
spread	edge growth	Growth on the edges of growth centers (existing or new)
slope resistance	(affects all types)	Can deter growth from steeper gradients
road-gravity	road influenced	Growth occurring along transportation networks, encouraged due to the road-gravity factor

SLEUTH also has another group of growth rules for "self-modification" where the growth rate and growth parameters can be adjusted if growth rates becomes too high or low and hit defined thresholds as the model is iterating from the initial condition to the final prediction output (Clarke et al. 1997; Clarke and Gaydos 1998). By applying the five growth rules as well as the self-modifying rules, emergent behavior evolves that is intrinsically more complex than if the initial five growth rules were applied on their own (Clarke and Gaydos 1998).

SLEUTH has been used in previous studies both nationally (Clarke and Gaydos 1998; Herold et al. 2003) and internationally (Rafiee et al. 2009; Wu et al. 2009) to predict urban growth rates and patterns. The idea of using SLEUTH to examine how predicted growth varies using different scenarios was also exercised by Jantz et al. (2004) in a study of the Baltimore-Washington metropolitan area where three different scenarios were examined: Current trends, managed growth, and ecologically sustainable growth. Their 2004 study in particular sets the ground work for the scenarios that are addressed in this study and shows how the results can effectively show a range of impacts of the different planning strategies. Other studies have also found evidence that SLEUTH's accuracy increases at coarser or more regional scales (Jantz et al. 2004; Wu et al. 2009). The results of a spatial accuracy assessment revealed some of the limitations of the model in simulating local patterns of urban development and show that the model works well at a scale of the 11-digit hydrologic unit code (HUC) watersheds as well as at the county-level (Jantz et al. 2004). In a more recent study, Jantz et al. (2010) modified SLEUTH to incorporate more social and economic factors and obtain more accurate results. The study area included the entire Chesapeake Bay Watershed and separated the watershed into smaller divisions to categorize development density. Similar to the study presented here, a recent study by Jantz et al.(2010) added areas that were attractive for development, as opposed to just including areas that are excluded from development. SLEUTH is vital in providing the necessary information to planners and policymakers who need to understand what land use changes can reasonably be expected (Torrens and O'Sullivan 2001; Yeh and Li 2001; Herold et al. 2003).

The New Jersey Office of State Planning's Population and Employment Distribution (PED) model (Reilly 1997a; 1997b) was coupled with SLEUTH to provide SLEUTH with amounts of expected development based on population and employment rates. PED uses predicted population and employment growth in minor civil divisions and determines a subsequent urbanization footprint required to accommodate such growth, which is input into the SLEUTH model. By including variables such as headship rates and land availability in minor civil divisions, PED provides a depiction of growth patterns at a more local level.

The Chesapeake Bay Watershed Model (WSM) was created by the Chesapeake Bay Program (http://www.chesapeakebay.net) in 1982 to help guide efforts to improve the water quality in the Chesapeake Bay. The model divides the Chesapeake Bay watershed into model segments based on soil properties, model calibration station locations, terrain, model running time as well as other pertinent data. These model segments are overlaid with county and state borders to create what the CBPO calls "county segments" or "cosegments" (Hopkins et al. 2000). Edge-of-stream nutrient loading rates developed by the US EPA using Hydrological Simulations Program-Fortran (HSPF)(Bicknell et al. 1993) were generated through modeling of the entire Bay watershed.

3.4 Methods

A set of seventeen representative watersheds were selected to examine how land cover changes varied throughout the study region. Four larger watersheds were chosen based on size, location, and potential for land cover change. Within each of these four watersheds, an additional thirteen subwatersheds were delineated to span a range of varying basin sizes. The four larger watersheds are: Bohemia (Boh) River, Trappe (Trp) Creek, Tred Avon (TrdA) River, and the Wicomico (Wic) River. A summary of each watershed's size, slope and urban area (based on current conditions) is shown in Table 3. Figure 1 shows the location of each of these. Note that each subwatershed is nested inside the larger watershed. For example, the Wicomico 1 watershed includes the land area covered by Wicomico 2, 3, and 4.

For the sake of the analysis, the results from only the Wicomico watersheds will be presented in depth. The remaining results will be included in the Appendices. Figure 2 shows a closer view of the Wicomico watersheds.

Table 3. Study Watersheds Summary

Subbasin	Area [km^2]	Land Slope [m/m]	Urban Area %
Bohemia River 1	94.3	0.034	5.0
Bohemia River 2	27.2	0.024	12.9
Bohemia River 3	7.8	0.018	21.7
Bohemia River 4	2.3	0.014	0.0
Trappe Creek 1	25.9	0.009	21.6
Trappe Creek 2	7.3	0.008	24.0
Trappe Creek 3	2.6	0.005	5.7
Tred Avon River 1	117.1	0.009	19.6
Tred Avon River 2	24.6	0.008	40.2
Tred Avon River 3a	7.8	0.005	42.8
Tred Avon River 3b	7.8	0.01	35.0
Tred Avon River 4a	3.4	0.006	68.6
Tred Avon River 4b	3.4	0.007	2.7
Wicomico River 1	250.5	0.008	30.5
Wicomico River 2	81.6	0.007	22.0
Wicomico River 3	11.9	0.007	43.3
Wicomico River 4	2.6	0.004	76.1

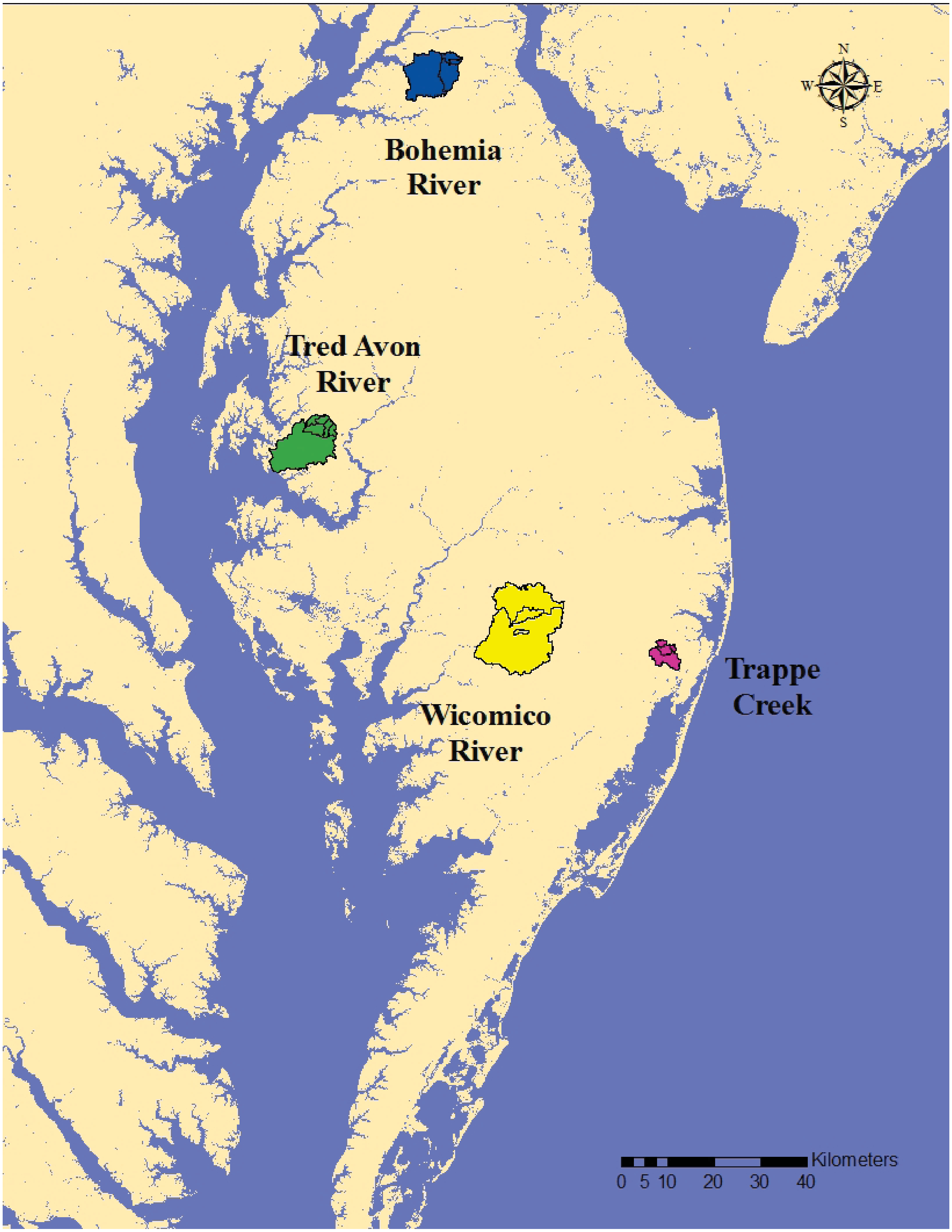

Figure 1. Study Watershed Locations

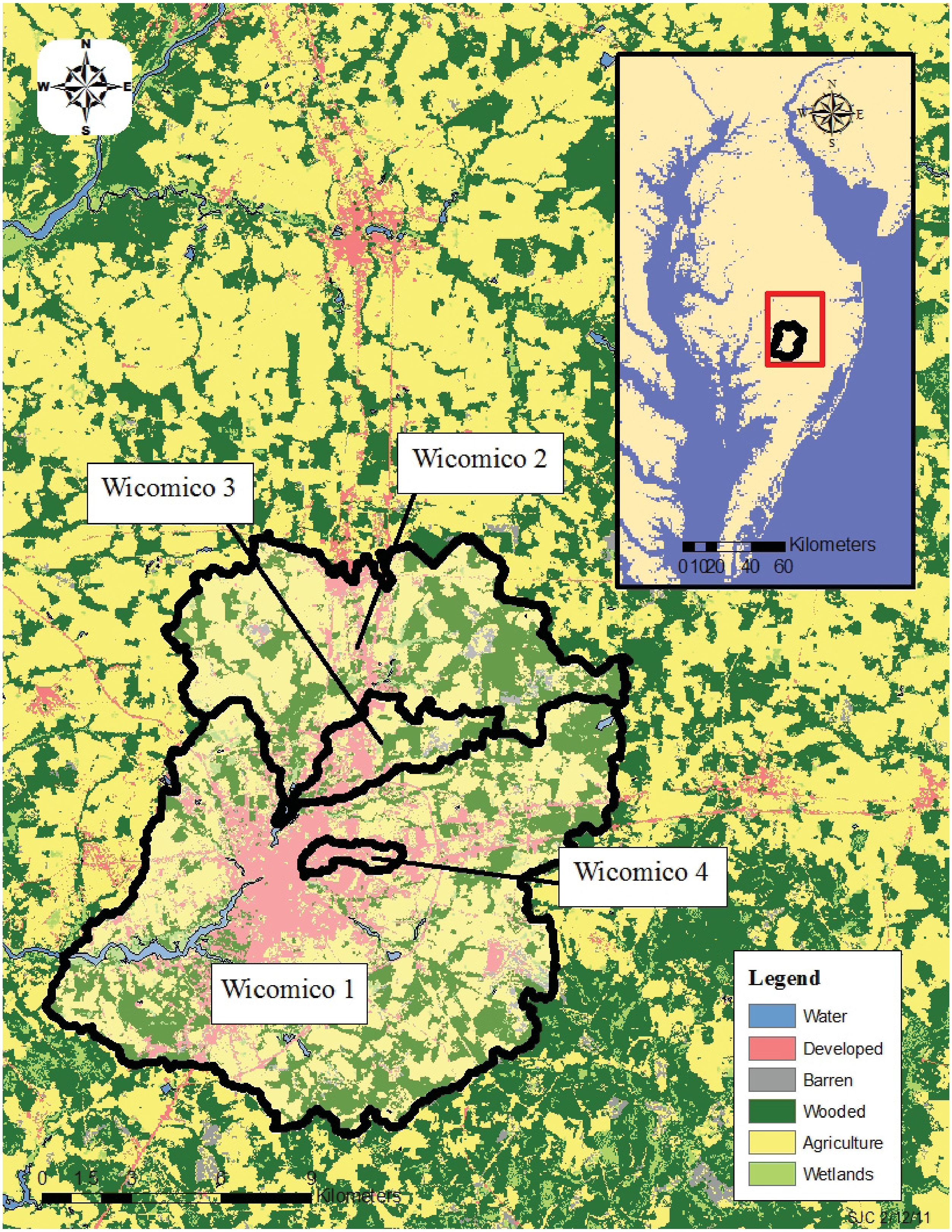

Figure 2. Location of the Wicomico River Watersheds

The SLEUTH model, coupled with the predicted urban footprints produced by the PED model, generated 10 realizations for each of three planning scenarios. Since the SLEUTH model was run by Claire Jantz, it was her decision to create 10 realizations for each scenario based on her past experience and modeling constraints. The three SLEUTH scenarios have been used in previous studies (Jantz et al. 2004) and are described below:

1. Current trends- This scenario uses the exclusion and attraction layers from the calibration stage of SLEUTH, maintains currently protected lands such as wetlands and parks, and increases resistance to infill of existing urban areas. A limited amount of planning information is also included.

2. Planning trends- As its name denotes, the planning trends scenario uses a wide breadth of planning data and is compilation of a number of current local and regional planning efforts with an emphasis on smart growth. There are also increased measures to preserve wetlands, critical conservation areas, riparian buffers, floodplains and designated Chesapeake Bay critical areas.

3. Resource scarcity- The measures and management strategies use in the planning trends scenario are maintained with even stricter enforcement of smart growth policies and resource protection. To address the effects of the climate change in the next few decades, this scenario includes inundation due to a predicted sea level rise.

The exclusion/attraction layers used as input for each of these scenarios (without PED weights) are shown in Figure 3.

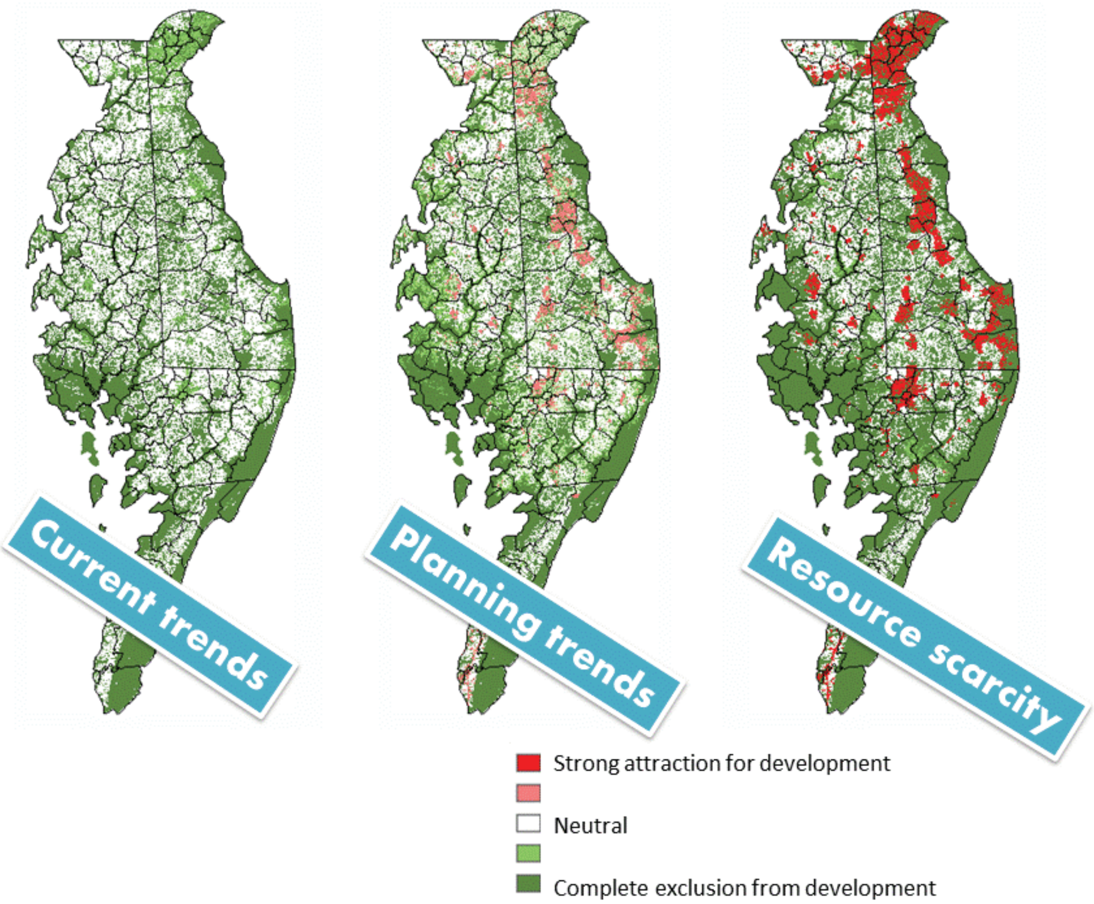

Figure 3. Attraction/ Exclusion Weighting used in SLEUTH scenario input without PED weights (Image used with permission of Claire Jantz)

Each of these SLEUTH scenarios was combined with each of the three different PED model growth scenarios ultimately producing nine different land cover scenarios. The attraction for development throughout the Delmarva Peninsula due to these PED population growth scenarios is shown in Figure 4, where headship (HS) indicates the growth scenario used.

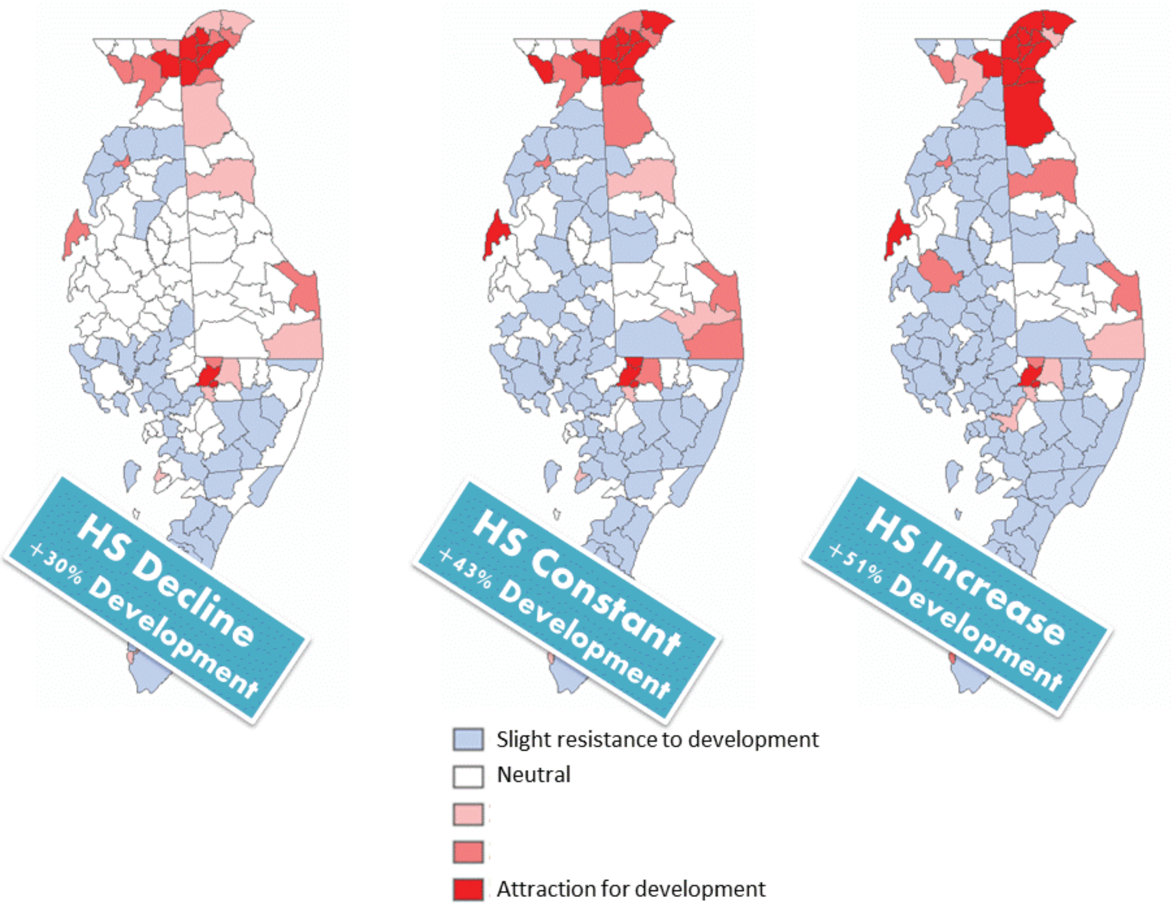

Figure 4. PED Growth Rate Weighting used as Input to SLEUTH, where HS Decline is the low growth scenario, HS Constant is linear growth, and HS Increase is the high growth scenario (Image used with permission of Claire Jantz)

Using the CBPO method to estimate changes in nitrogen, phosphorus, and sediment requires quantification of CBPO land use for each study area. The input data included 90 SLEUTH land cover rasters; the 2005 C-CAP initial land cover conditions; the 2001 National Land Cover Dataset (NLCD) (Homer et al. 2007); and GIS-based shapefiles of each study watershed area. The land cover predictions created by SLEUTH in this study are categorized using NOAA's Coastal Change Analysis Program (NOAA Coastal Services Center 2009), a system developed for use in coastal applications of the NLCD and gives particular emphasis to wetlands. These data were converted to the CBPO land cover description using the translation method which was developed and executed as described in Appendix A. The final step of the conversion is to translate CBPO land cover to CBPO land use for the water quality analysis using the conversion process created by the CBPO (Hopkins et al. 2000).

Quantifying the changes in nutrient runoff was done using a modification on the Simple Method (Schueler 1987). Once the amount of CBPO land use is tabulated for each watershed, these areas are multiplied by the corresponding loading coefficient (nutrient kg/year/hectare) developed by Moglen (2007) from CBPO data for each land use and cosegment. Then the total annual nutrient load is found by taking the sum all of the loads calculated in each cosegment within the watershed. The nutrient loads used in this process were developed in Phase 4.3of the CBPO Watershed Model and provided by Gary Shenk (2006). It should be noted that the rates are from the edge-of-stream perspective, so all of these loads account for total nutrients reaching a stream, regardless of how the nutrients may cycle within the stream as they travel downstream.
When watersheds intersected cosegments that were not within the Chesapeake Bay Watershed, loading rates were not available and were estimated based on the loading rates of the surrounding cosegments.

Peak flows were estimated using the SLEUTH output to assess the magnitude of change from the 2005 peak flows to 2030. These flows were calculated based on watershed characteristics and a design storms input into TR-20 (NRCS 1992). All of the watershed characteristics remained the same between each run with the exception of land cover which required conversion from the C-CAP land cover categories to curve numbers (CN). For simplicity, the results are focused on the 2-yr, 24-hr storm is more sensitive to changes in land use due to its small size as well as the 100-yr, 24-hr storm, which commonly used for flood mapping. Both of these storms are typical design storms often used in the design of best management practices as well as hydraulic structures.

To quantify the changes in land cover between SLEUTH scenarios and realizations, curve numbers must be developed for use as TR-20 input. Without a pre-existing conversion from C-CAP land cover categories to CNs, a conversion process was created that combines a number of previously established conversion systems. All of the CNs used are based on TR-55 (NRCS 1986) system for assigning curve numbers. Table 4 shows the C-CAP to curve number assignments used. Curve number values were taken from the Nonpoint Source Pollution and Erosion Comparison Tool (N-SPECT) (NOAA 2004) and also assigned based on information tabulated in TR-55 (NRCS 1986). Table 4 shows the final conversion matrix that was used as well as the source for individual conversions, when the values were borrowed from previous studies.

Table 4. C-CAP Land Cover to Curve Number Conversion

C-CAP					**Soil Type***			
Value	**Description**	**NRCS Description**	**TR-55 Treatment**	**TR-55 Condition**	**A**	**B**	**C**	**D**
1	Developed, High Intensity				77	85	90	92
2	Developed (High, Medium, Low, Open)**	1/4 Acre Residential			61	75	83	87
3	Developed, Medium Intensity				61	75	83	87
4	Developed, Low Intensity				54	70	80	85
5	Developed, Open Space				39	61	74	80
6	Cultivated Crops	Row Crops	Straight Row	Good	67	78	85	89
7	Pasture/Hay	Pasture, Grassland, or Range		Good	39	61	74	80
8	Grassland/Herbaceous	Pasture, Grassland, or Range		Good	39	61	74	80
9	Deciduous Forest	Woods		Good	30	55	70	77
10	Evergreen Forest	Woods		Good	30	55	70	77
11	Mixed Forest	Woods		Good	30	55	70	77
12	Scrub/Shrub	Brush		Good	30	48	65	73
13	Palustrine Forested Wetland				95	95	95	95
14	Palustrine Scrub/Shrub Wetland				95	95	95	95

C-CAP					Soil Type*			
Value	Description	NRCS Description	TR-55 Treatment	TR-55 Condition	A	B	C	D
15	Palustrine Emergent Wetland (Persistent)				95	95	95	95
16	Estuarine Forested Wetland				95	95	95	95
17	Estuarine Scrub/Shrub Wetland				95	95	95	95
18	Estaurine Emergent Wetland				95	95	95	95
19	Unconsolidated Shore	Fallow	Bare Soil		77	86	91	94
20	Barren Land	Fallow	Bare Soil		77	86	91	94
21	Open Water				100	100	100	100
22	Palustrine Aquatic Bed	Fallow	Bare Soil		100	100	100	100

*CN's from Table 2-2a in TR-55

**Based on NOAA Low-Intensity Developed

🟥 = NOAA N-SPECT (1986)

For each of the seventeen watersheds used in this study, the curve number, slope, and flow length were derived through GIS analysis and combined with a design storm as inputs to TR-20. TR-20 estimated the peak discharges based on the initial land cover conditions as well as all 90 SLEUTH realizations for the following design storms: 2-yr, 24-hr; 5-yr, 24-hr; 10-yr, 24-hr; 25-yr, 24-hr; 50-yr, 24-hr; 100-yr, 24-hr. For brevity, only the 2-yr, 24-hr storm and the 100-yr, 24-hr storm data are recorded here since the 2-yr storm is smaller and more sensitive to land cover change whereas the 100-yr storm models a more extreme event which is often used in flood mapping and planning decisions.

For each of the nine possible scenarios, 10 different realizations were created which vary slightly due to SLEUTH's inherently random growth placement. To evaluate how greatly the realizations differ, these variations were quantified using box and whisker plots which show the range between the first (Q1) and third quartiles (Q3), the median, and the "whiskers" which range from the upper limit (Q3 + 1.5 (Q3 - Q1)) to the lower limit (Q1- 1.5 (Q3 - Q1)). The coefficient of variation was also calculated for all ten realizations of each scenario, where the coefficient of variation (COV) is calculated as follows:

$$Cov = \frac{\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2}}{\frac{1}{n}\sum_{i=1}^{n}x_i} \cdot 100\% \qquad (1)$$

The COV was chosen because it is dimensionless and can be compared for watersheds that vary in size and correspondingly vary in the magnitude of discharge and nutrient loads.

3.5 Results

For each of the seventeen chosen watersheds, the annual sediment, phosphorus, and nitrogen loads as well as peak discharges were calculated based on the ninety unique SLEUTH land cover predictions for 2030 as well as the initial land cover conditions. The Wicomico watersheds were chosen as representative watersheds since they show typical results and are located completely with the Chesapeake Bay watershed (and thus existing loading rates could be used to estimate nutrient loads). For brevity, the Wicomico (Wic) results are shown here, however the other watersheds will be mentioned when and if their results differ markedly from those found in the Wicomico watersheds.

Since SLEUTH created 10 different realizations for each of the nine scenarios analyzed, it was necessary to examine and quantify how greatly these realizations differ. Figures 5 through 9 show a basic box and whisker plot for the realizations of the baselinear scenario vs. area, where each of the four areas listed correspond to one of the Wicomico watersheds starting with the smallest (Wicomico 4) to the largest (Wicomico 1). The values used to create these plots were the values of the nutrient load or peak discharge for each realization normalized by the mean value for all ten realizations as tabulated in Table 5. Exact values for these plots can be found in Appendix G.

Table 5. Mean (and normalizing values) for 10 SLEUTH realizations of the baselinear scenario in Wicomico watersheds

Watershed Name	Watershed Area (km^2)	TS (kg/yr)	P (kg/yr)	N (kg/yr)	Q_2 (m^3/s)	Q_{100} (m^3/s)
Wic 1	250	6,103,600	40,633	297,281	45	229
Wic 2	82	2,167,000	13,373	99,561	20	101
Wic 3	12	262,000	2,009	14,683	4	22
Wic 4	2.6	29,600	454	3,189	1	5

These results show that variation generally decreases with increasing watershed size. Sediment generally has the most variation, where nitrogen and phosphorus loads have smaller and more similar amounts of variation. Estimated peak flows for both the 2-yr and 100-yr storms both have minimal variation with less variation in the 100-yr flow values than the 2-yr values.

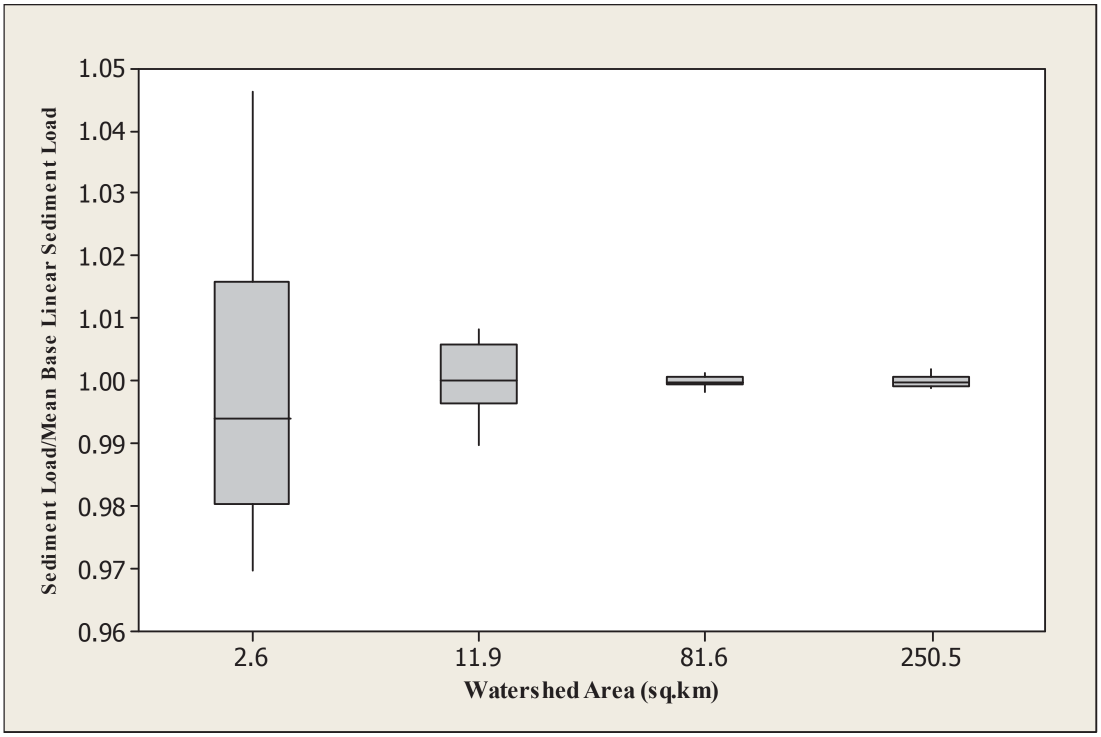

Figure 5. Sediment Variation between Realizations based on each Sediment Load Normalized by the Mean of all Base Linear Loads for all of the Wicomico Watersheds

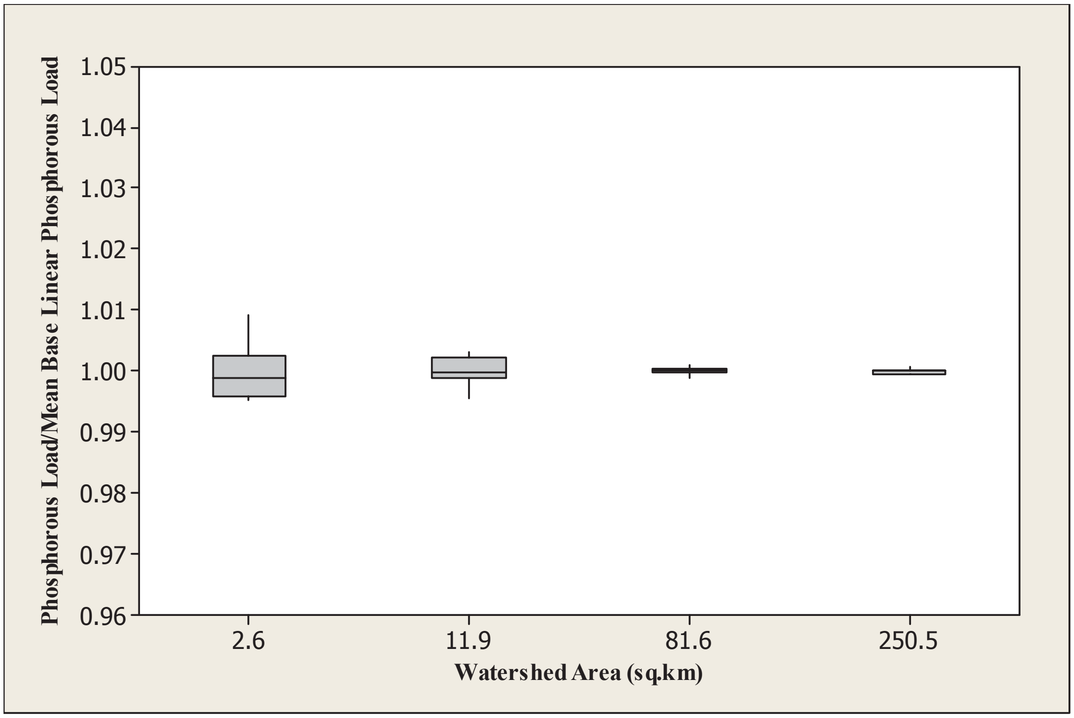

Figure 6. Phosphorus Variation between Realizations based on each Phosphorus Load Normalized by the Mean of all Base Linear Loads for all of the Wicomico Watersheds

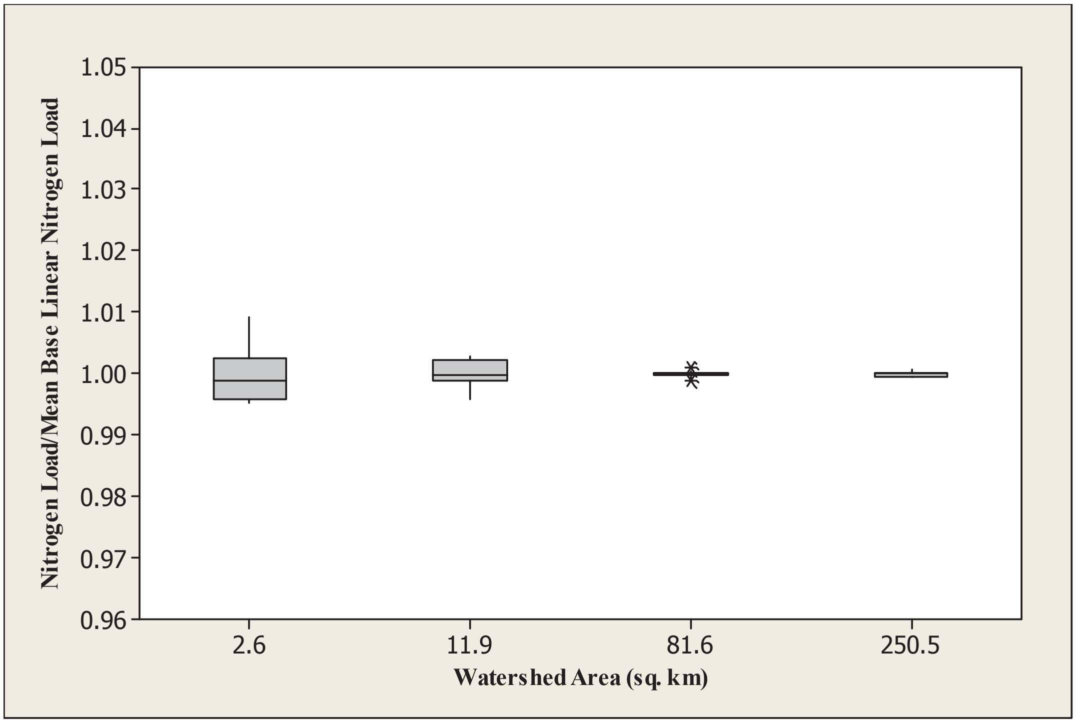

Figure 7. Nitrogen Variation between Realizations based on each Nitrogen Load Normalized by the Mean of all Base Linear Loads for all of the Wicomico Watersheds. (Asterisks indicate outliers.)

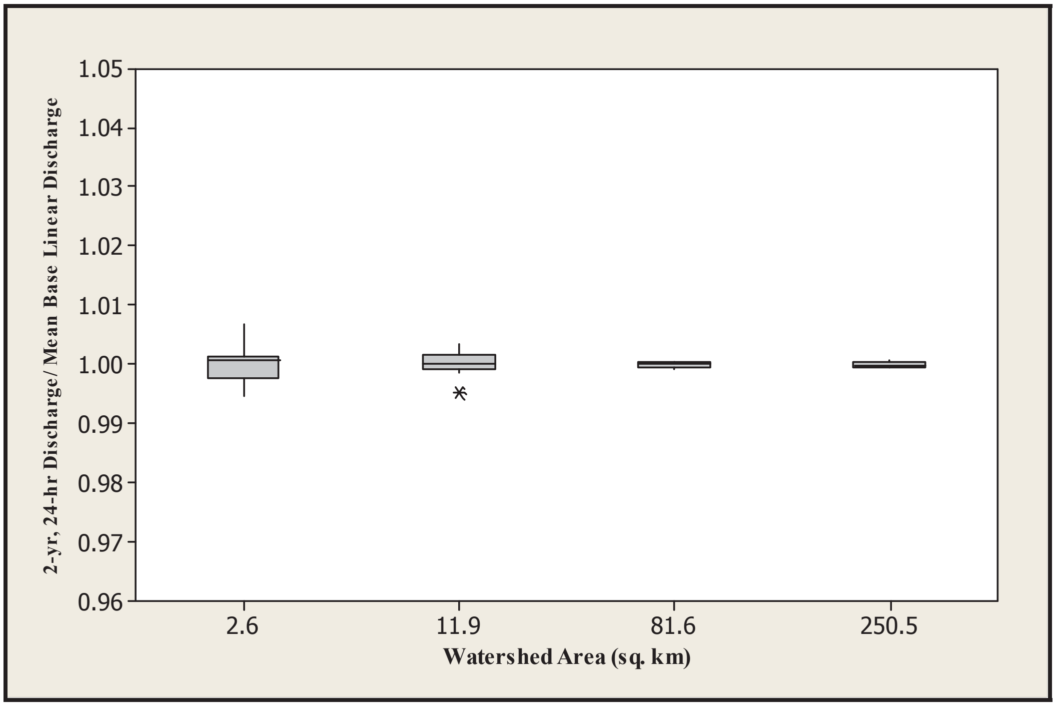

Figure 8. Peak Discharge (2-yr, 24-hr) Variation between Realizations based on each Peak Flow Normalized by the Mean of all Base Linear Flow for all of the Wicomico Watersheds (Asterisks indicate outliers.)

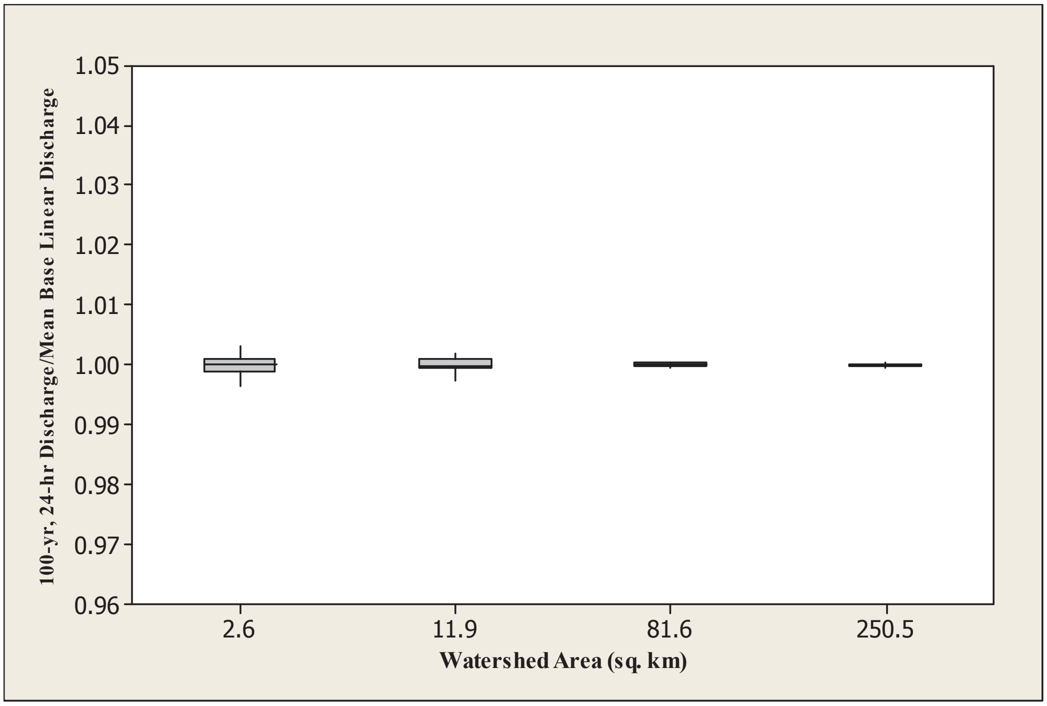

Figure 9. Peak Discharge (100-yr, 24-hr) Variation between Realizations based on each Peak Flow Normalized by the Mean of all Base Linear Flow for all of the Wicomico Watersheds

A further exploration of the variation between realizations and the watershed size of the Wicomico watersheds is shown below in Figures 10 through 14. Watershed areas are displayed in a log scale since the areas were originally chosen so that log(area) would roughly approximate a linear progression. Again, the smallest watershed size (2.6 km^2) corresponds to Wicomico 4 where watershed values decrease with increasing watershed area.

These results reflect similar trends as the box and whisker plots, where larger watersheds show lower coefficients of variations (COV) and the sediment load COVs are noticeably larger than the phosphorus and nitrogen load COVs.

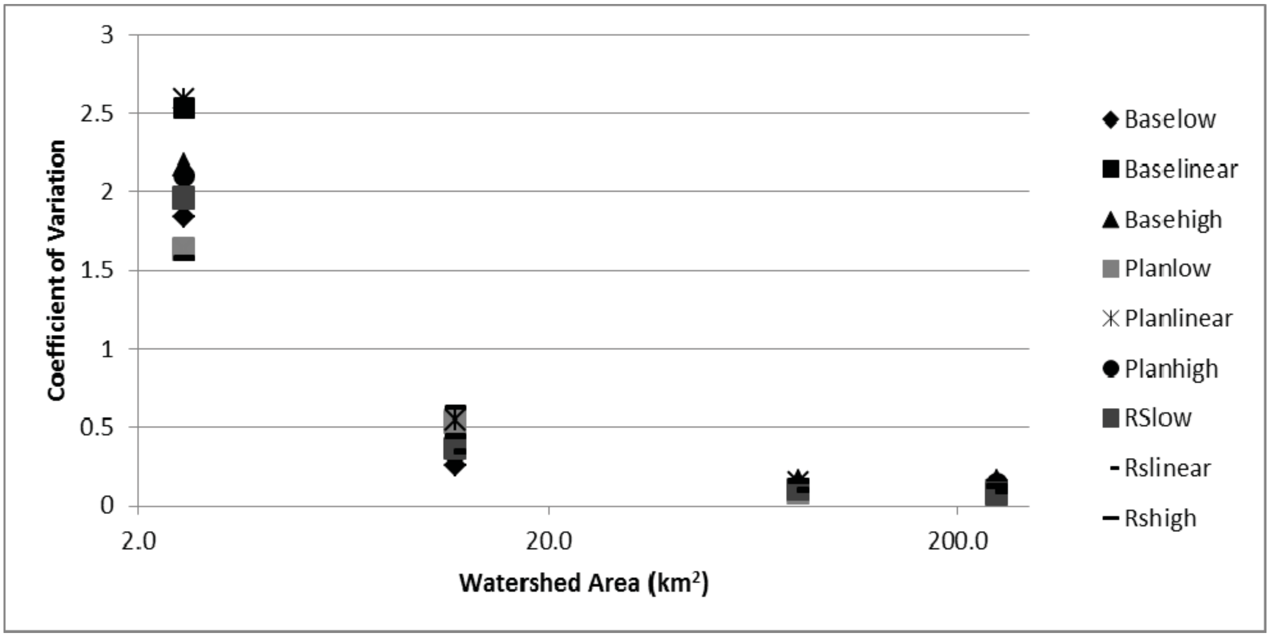

Figure 10. Sediment Load Coefficients of Variation vs. Watershed Area for the Wicomico Watersheds

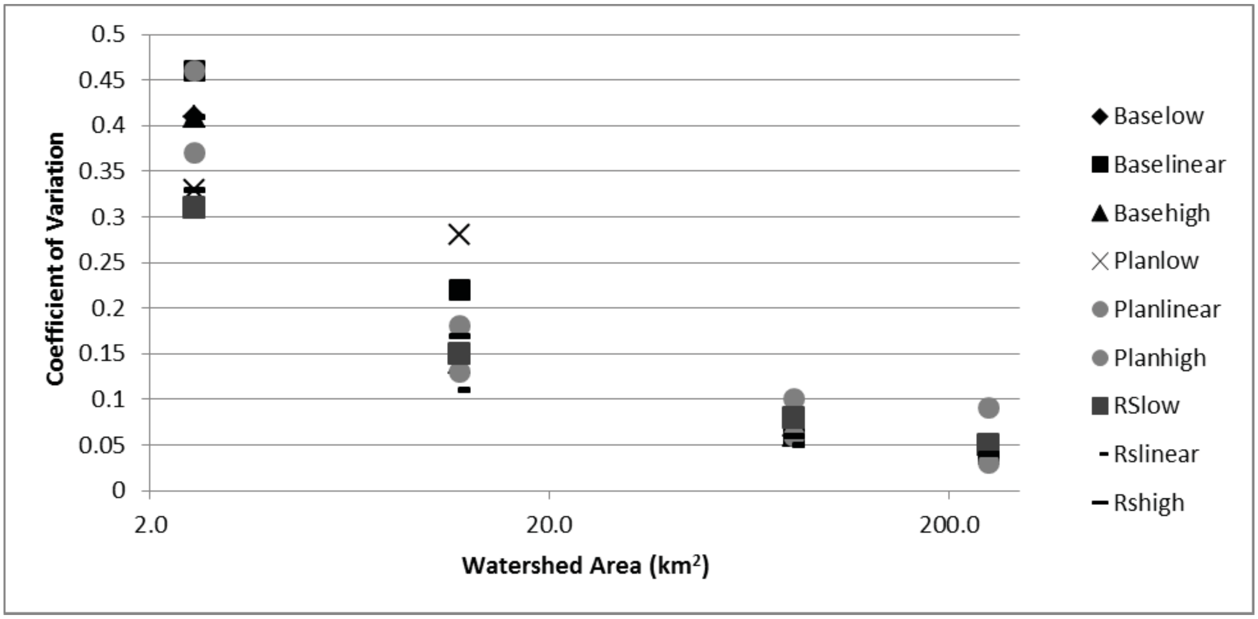

Figure 11. Nitrogen Load Coefficients of Variation vs. Watershed Area for the Wicomico Watersheds

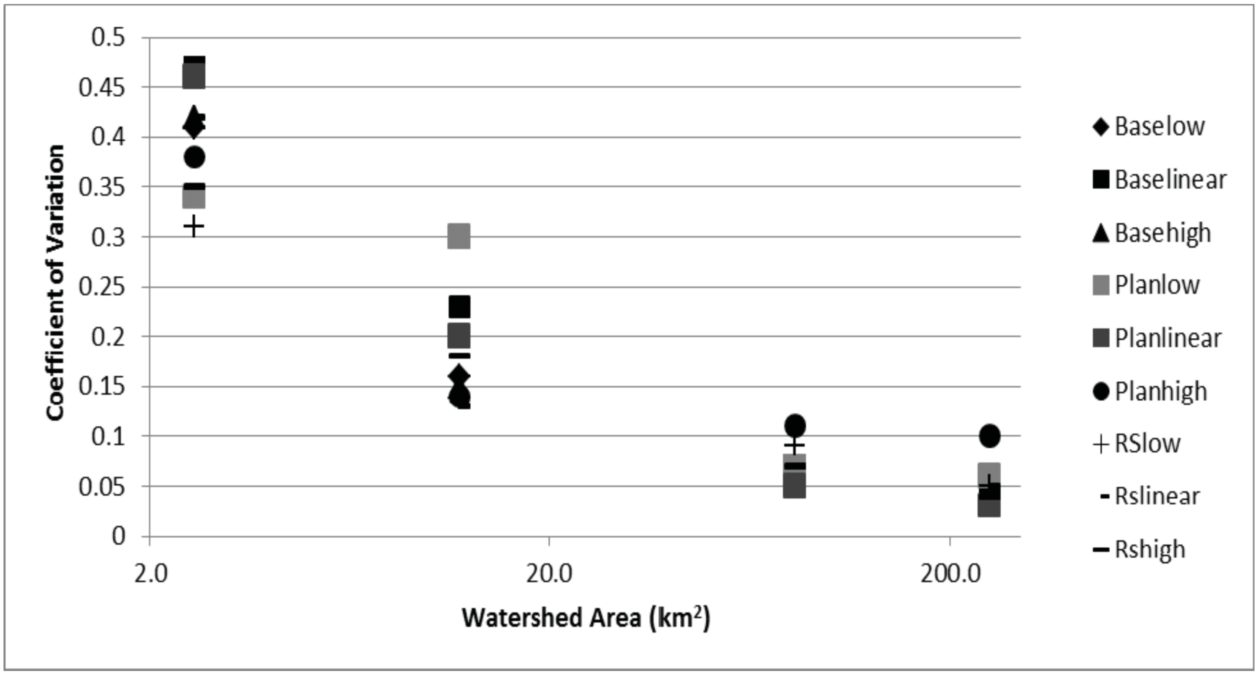

Figure 12. Phosphorus Load Coefficients of Variation vs. Watershed Area for the Wicomico Watersheds

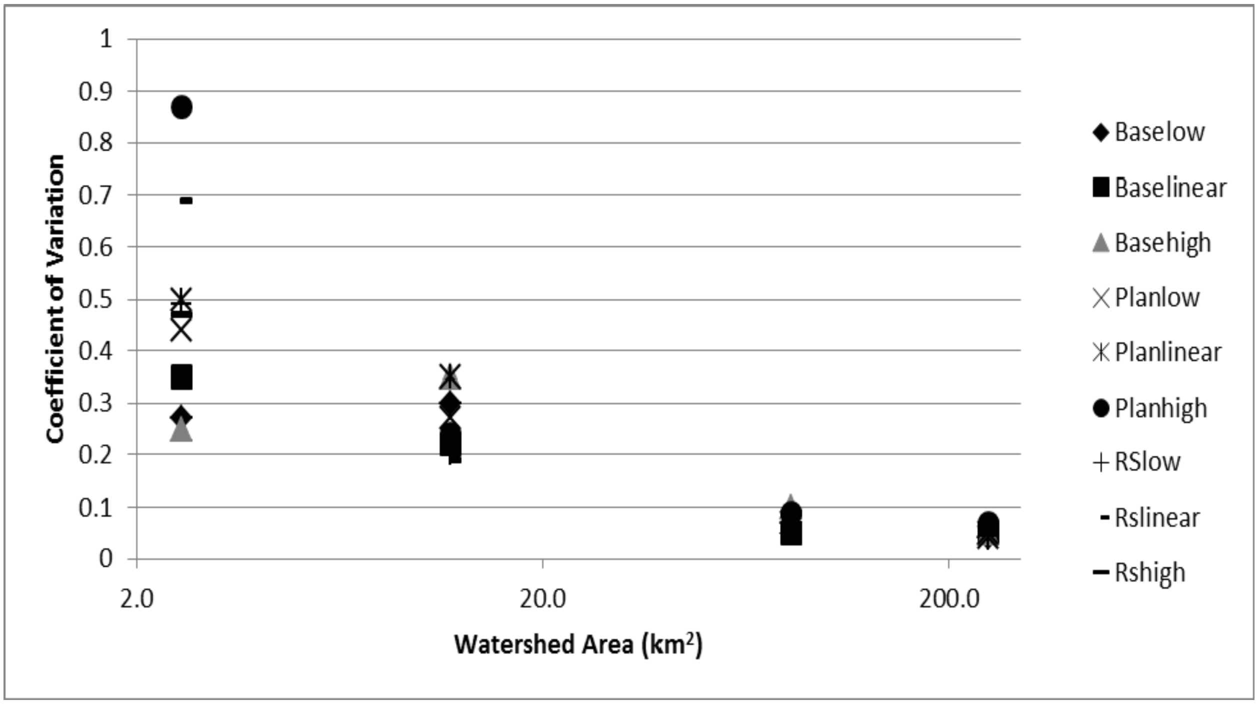

Figure 13. Peak Discharge (2-yr, 24-hr) Coefficients of Variation vs. Watershed Area for the Wicomico Watersheds

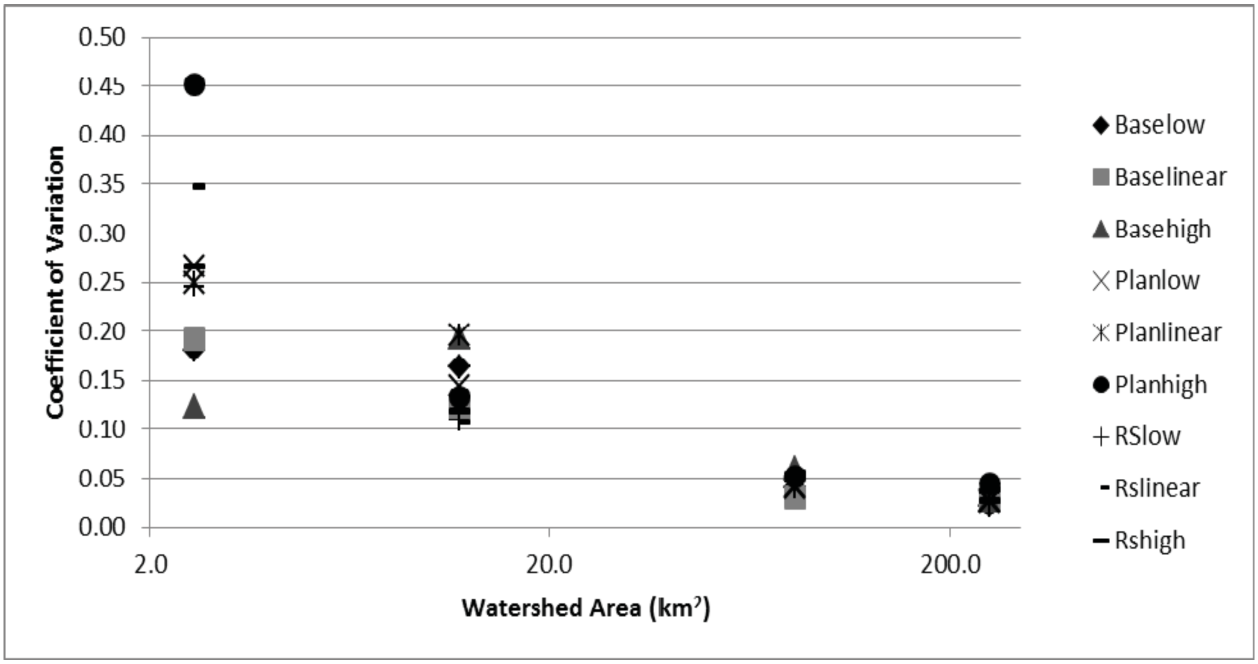

Figure 14. Peak Discharge (100-yr, 24-hr) Coefficients of Variation vs. Watershed Area for the Wicomico Watersheds

Nutrient loadings and peak flow results were compared for all watersheds to verify a logical pattern in the values. Figure 15 shows the average of all ten realizations across all nine scenarios vs. design storm size demonstrating an increase in flows with increasing storm size. Furthermore, the peak runoff per square kilometer was plotted vs. the average value for each of the scenarios (Figure 16). This shows typical catchment behavior where larger catchments generate lower peak flows per unit area due to longer times of concentration and more complex routing processes.

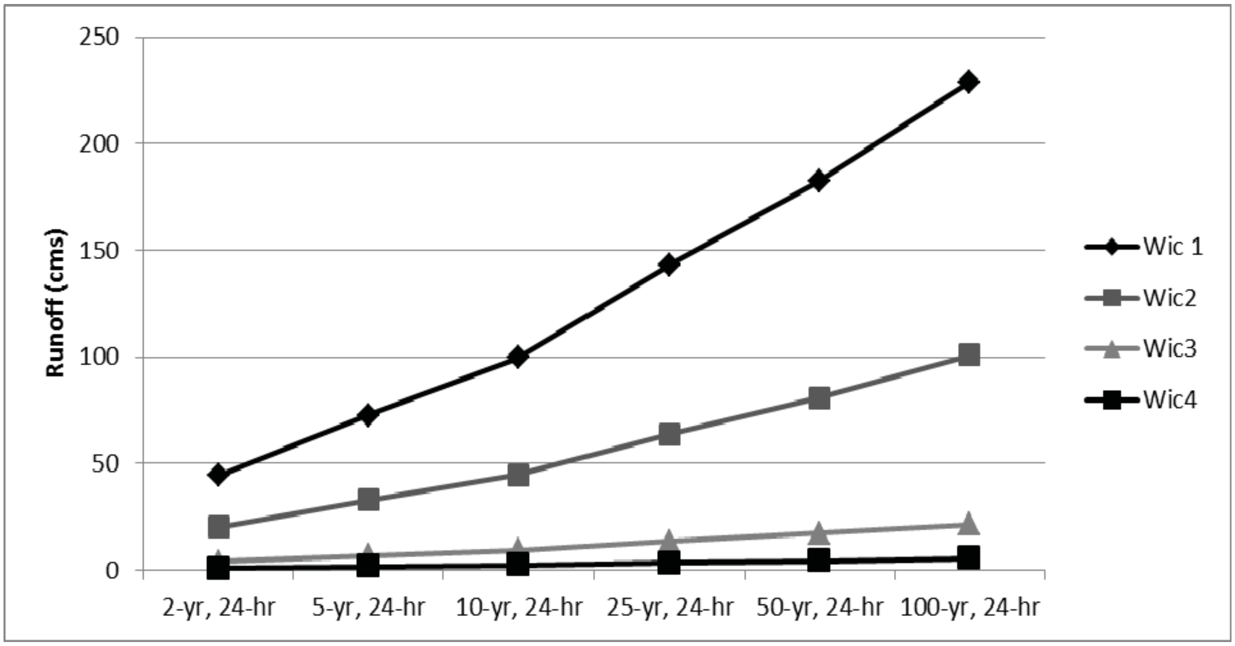

Figure 15. Average Peak Discharge (across all scenarios) vs. Design Storm for all Wicomico Watersheds

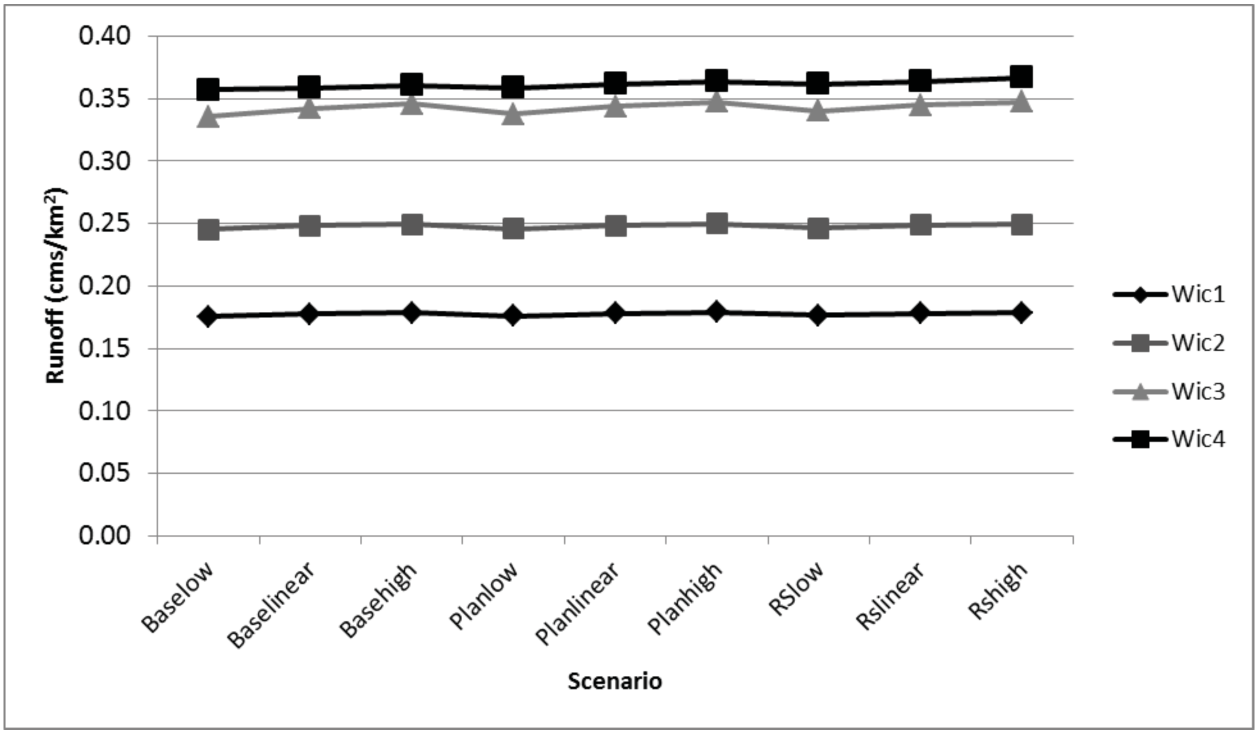

Figure 16. Peak Discharge (2-yr, 24-hr) Normalized by Area vs. Scenario for all Wicomico Watersheds

Each PED growth scenario coupled with a SLEUTH scenario creates a unique urban growth pattern varying in spatial layout and magnitude. To understand the effects of each of the nine combined scenarios, the differences in predicted land cover were examined. Figure 17 shows how growth can differ between scenarios. The first realization of the initial conditions, the base linear scenario, the RS low scenario and the base high scenario are shown here for Wicomico demonstrating increased development in all of the predicted scenarios and the highest amount of development in the base high land cover prediction.

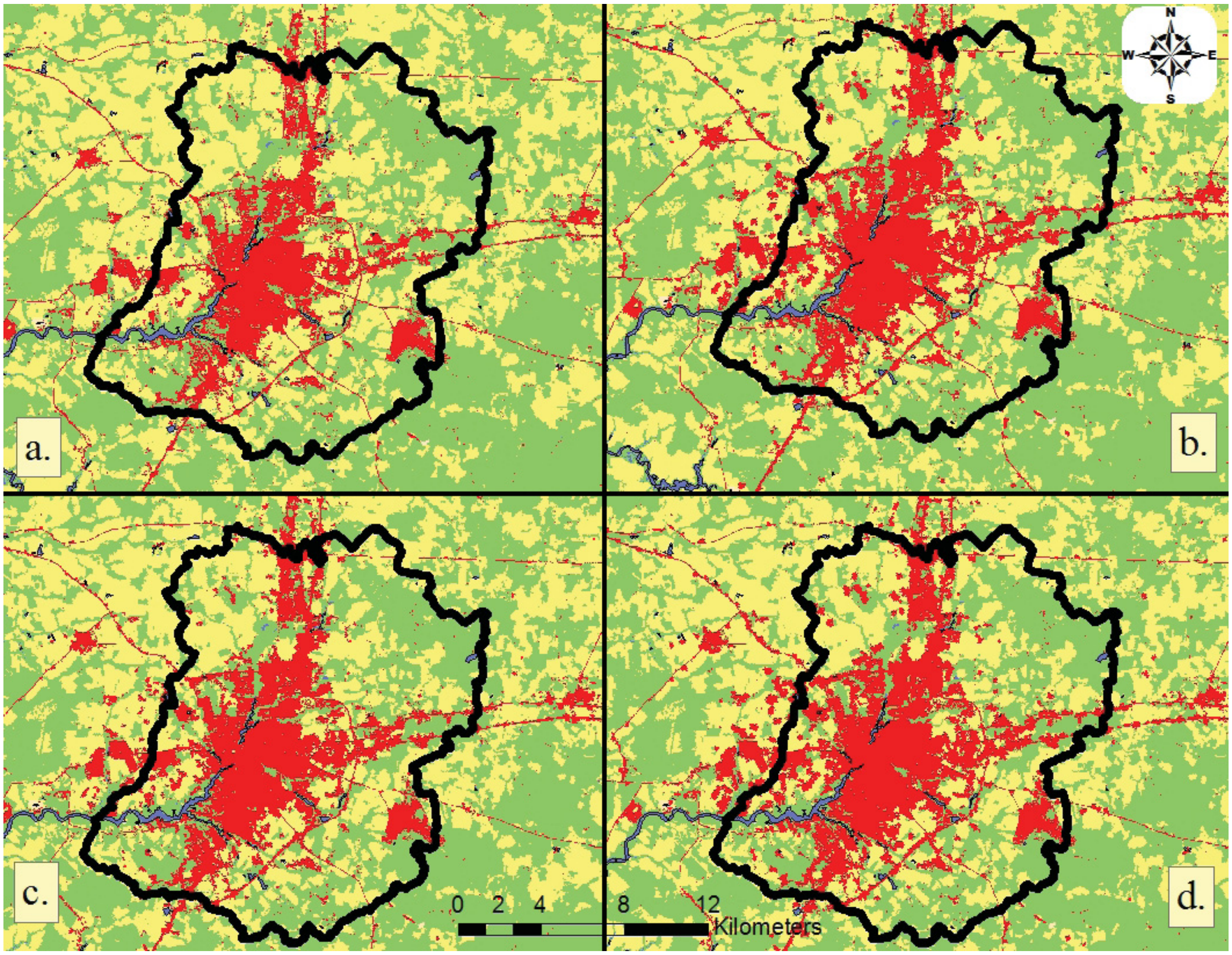

Figure 17. Development in Salisbury, MD in the Wicomico 1 watershed in (a) C-CAP 2005 (initial conditions), (b) a realization of the base linear scenario, (c) a realization of the resource scarcity low scenario, and (d) a realization of the base high scenario

The land cover as shown in Figure 17 is the direct output from the SLEUTH model, which was used to estimate nutrient loadings. These land uses, or more importantly how these land uses changed from the initial land use conditions, are the most telling indicators of how nutrient loadings will change. They are also responsible for explaining changes in the composite watershed curve number and thus the changes in the peak discharges. Figures 18 through 21 illustrate the amount that each land use has changed as a percentage of the original land use in the initial land use conditions layer for each of the Wicomico watersheds.

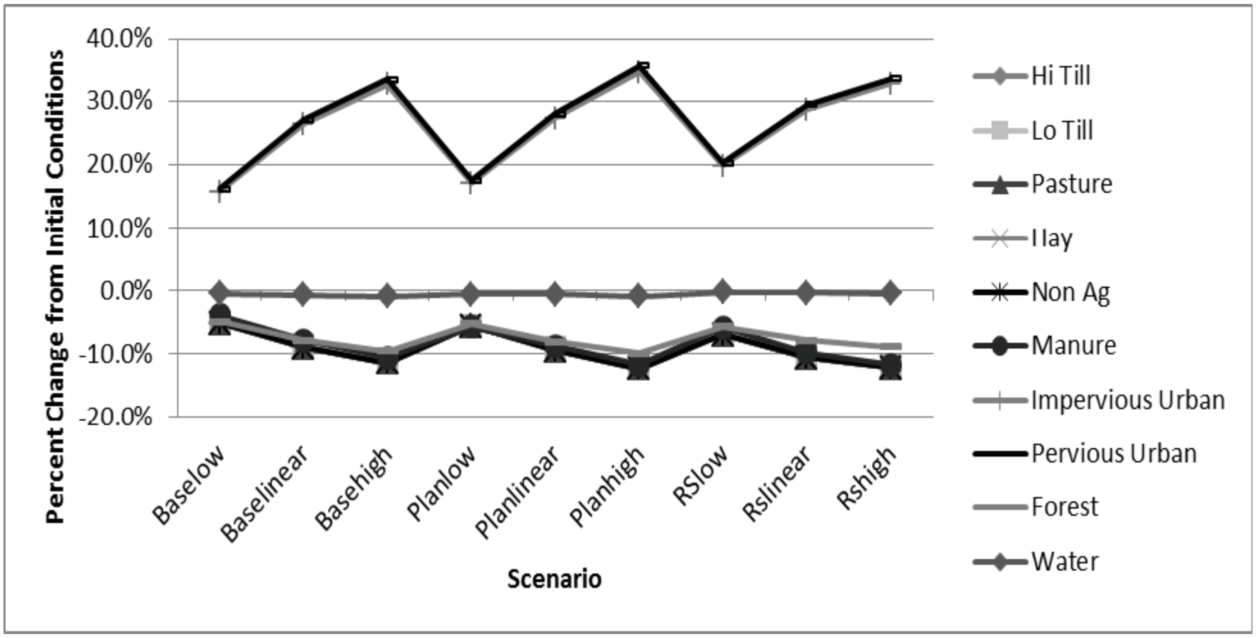

Figure 18. Average Percent Change in Land Use from the Initial Conditions Land Cover for Wicomico 1

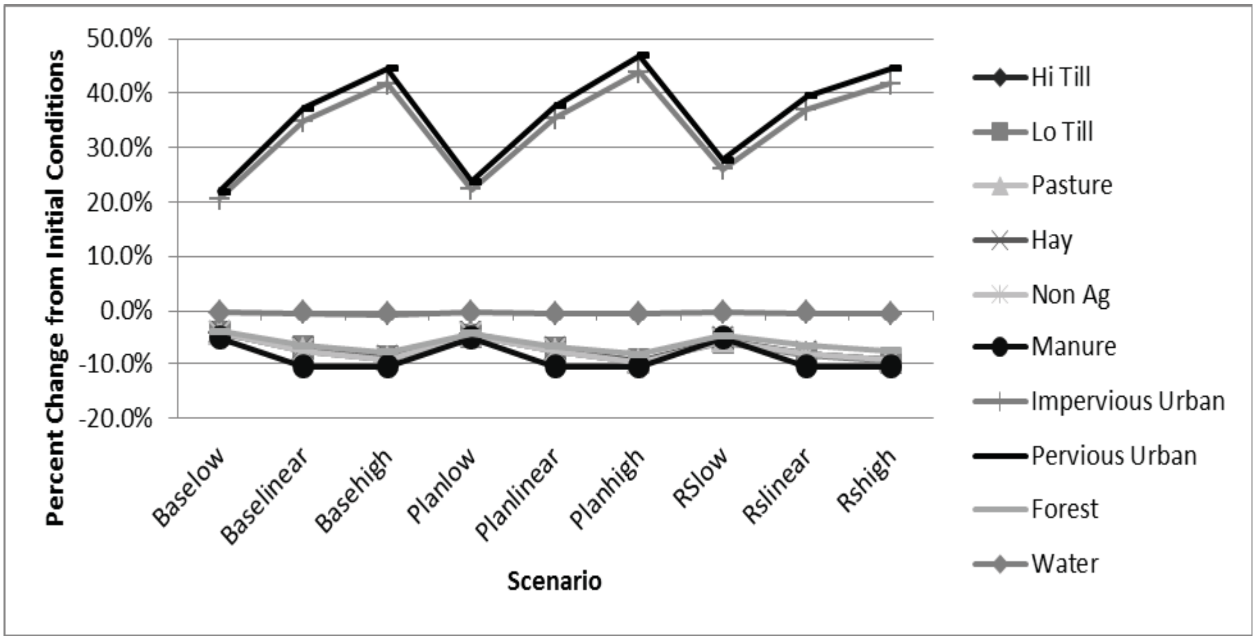

Figure 19. Average Percent Change in Land Use from the Initial Conditions Land Cover for Wicomico 2

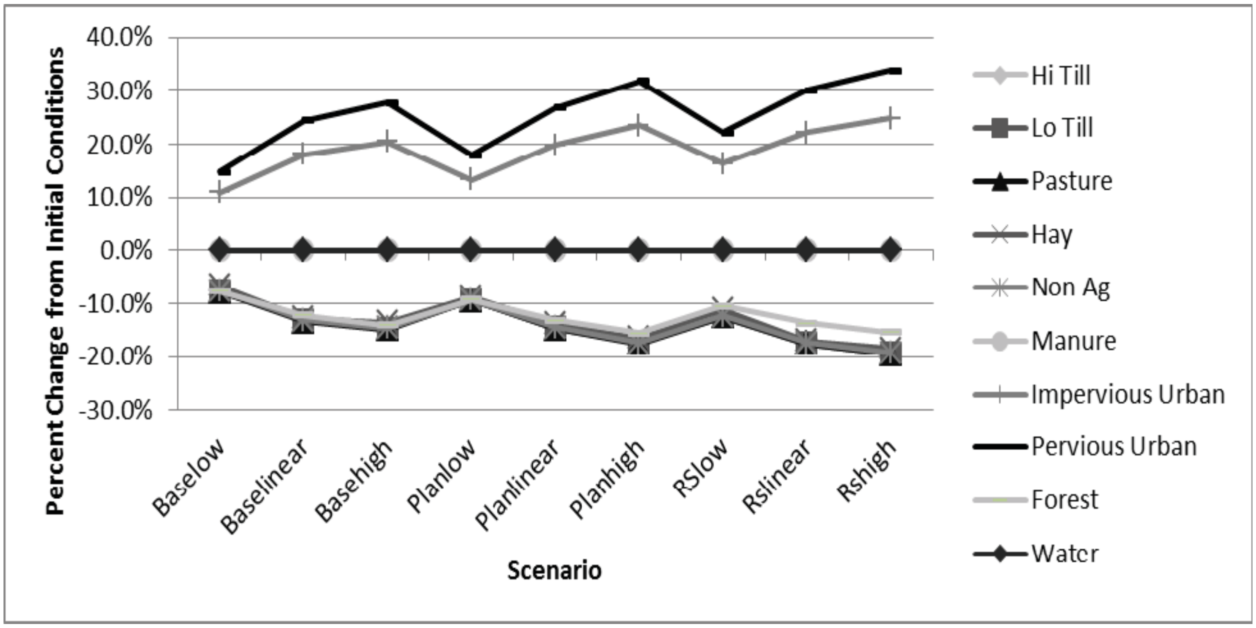

Figure 20. Average Percent Change in Land Use from the Initial Conditions Land Cover for Wicomico 3

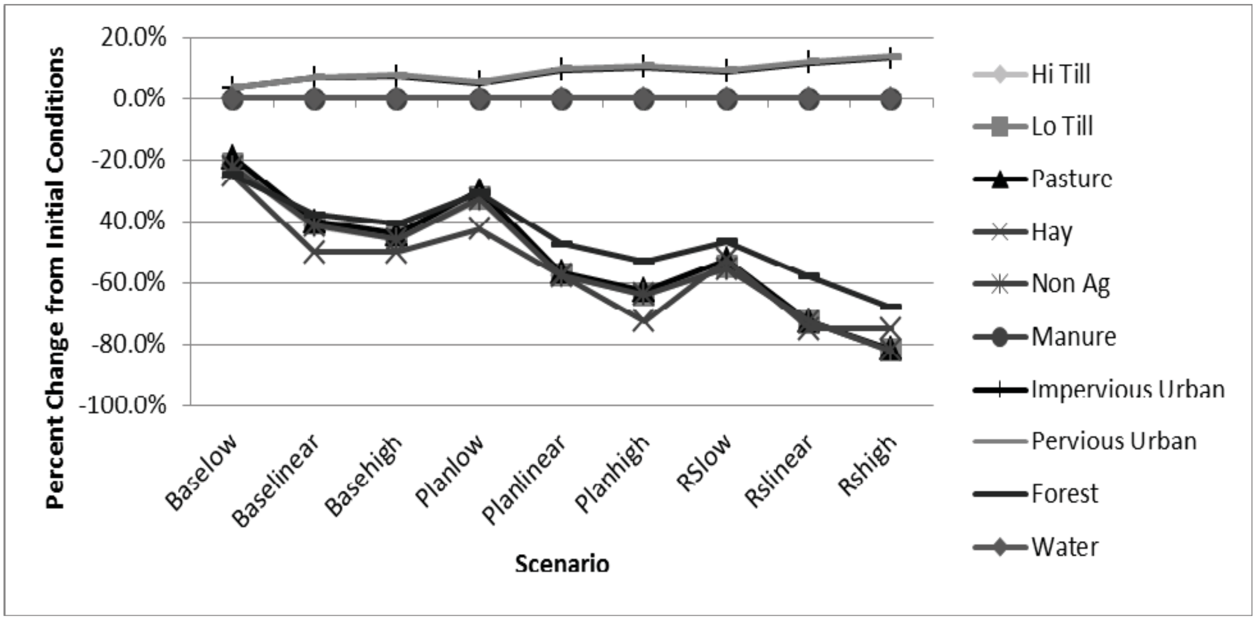

Figure 21. Average Percent Change in Land Use from the Initial Conditions Land Cover for Wicomico 4

In each of the four larger watersheds, as is consistent with the other thirteen watersheds in this study, impervious urban and pervious urban land use increased, while all other land uses either decreased or remained unchanged. In a few cases and especially in smaller watersheds, the percent change in a land use category or categories is large, such as values up to -80 percent in the Wicomico 4 watershed. This is a deceptive number since although the percent change is large, it is a consequence of the original amount of the land use being so small that a relatively small decrease in this land use (due to it being replaced by developed land) makes the calculated change large.

The final step is to use the land cover/land use data to estimate the resulting effects on peak flows and nutrient loads. These results are focused on the amount of change in each predicted value in comparison to the estimated values for the initial land use conditions. In all cases, as it was found with land use change, the amount of change in smaller watersheds (i.e. Wicomico 4) produces a larger change in hydrologic behavior since smaller watersheds are more sensitive to small changes in land cover and the resulting change in discharge or nutrient loads. Note that all values of annual nutrient loads as well as the change in loads for all seventeen watersheds can be found in Appendix E.

Figure 22 shows how the predicted sediment loads change from the base 2005 condition for all of the Wicomico watersheds. This result is typical of all seventeen watersheds which were found to have decreases in sediment loads for all scenarios ranging from -0.4% to -22.4%. It was also found that the predicted sediment loads decrease with higher PED population growth rates. In the Wicomico and Trappe watersheds, the change in sediment generally decreases with increased land management (i.e. planning scenario and resource scarcity scenario). However in most of the Tred Avon and Bohemia watersheds, linear growth and especially high growth scenarios demonstrated higher predicted sediment loads for both planning trends and resource scarcity in most watersheds. These differing trends are illustrated in Figure 23.

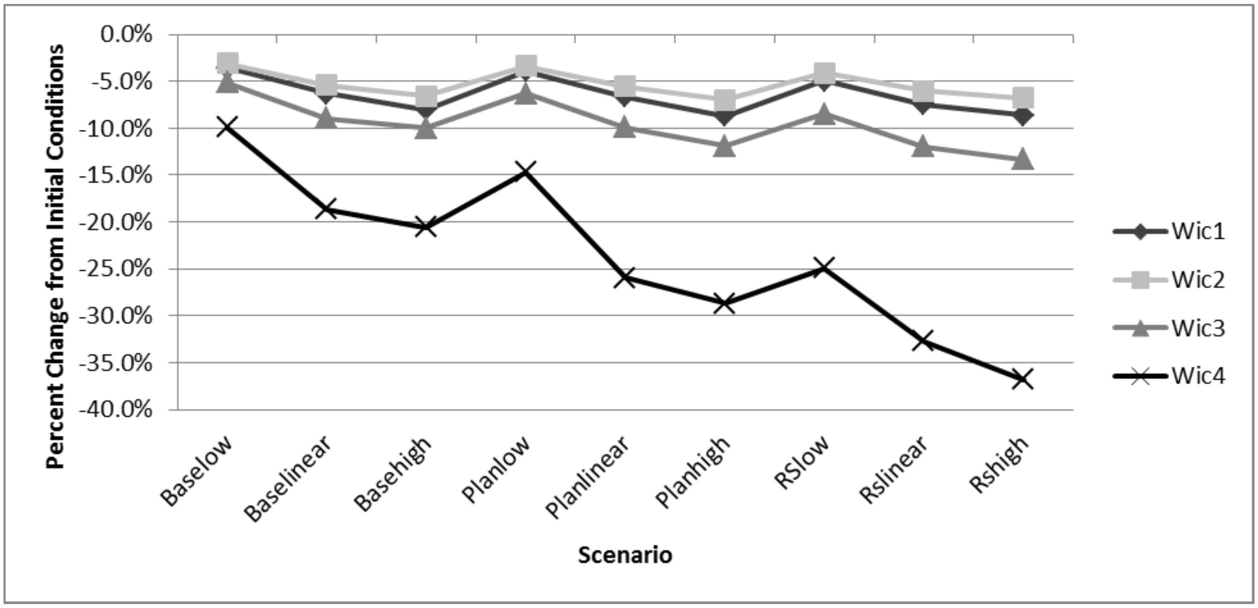

Figure 22. Average Percent Change in Sediment Loads from the Initial Land Use Conditions for the Wicomico Watersheds

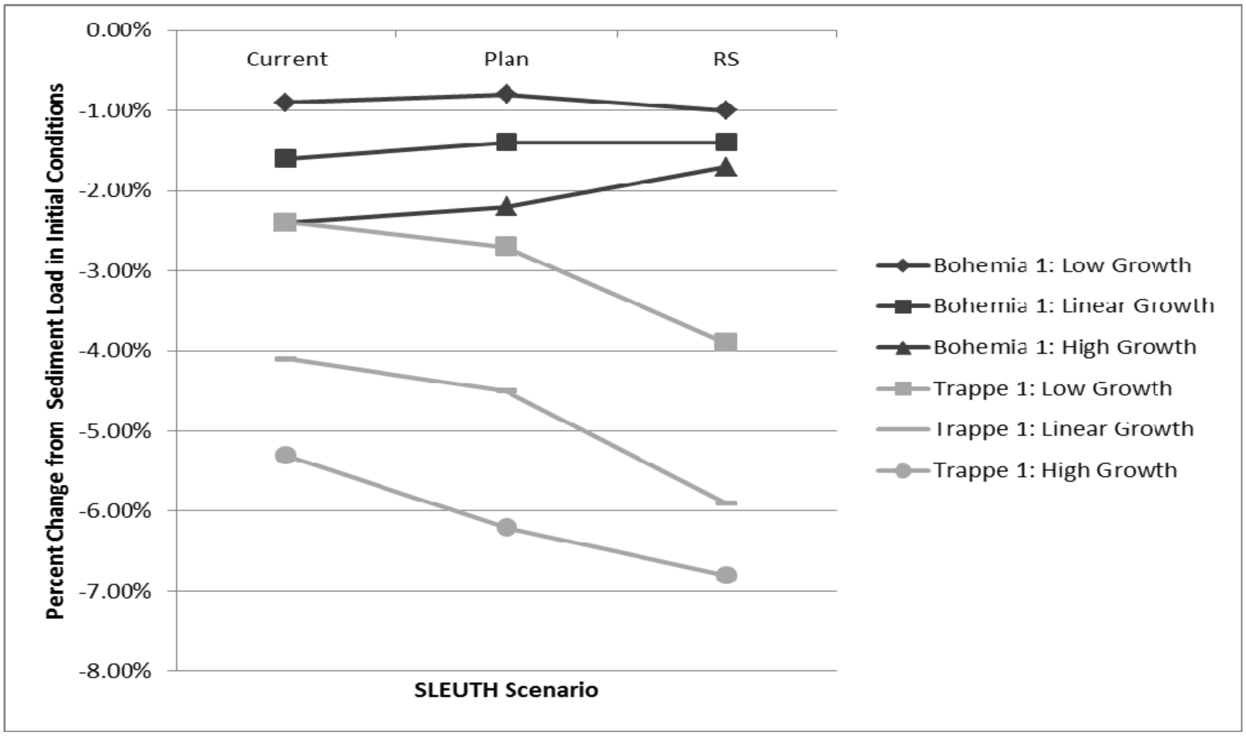

Figure 23. Change in Sediment Loads from Initial Land Use Conditions vs. SLEUTH Planning Scenario

Similar to sediment, the predicted nitrogen loads all decrease from the initial land use conditions and decrease with increasing growth for all seventeen watersheds, with changes ranging from -0.2% to -6.5%. The change in nitrogen loads for the Wicomico watersheds are shown in Figure 24. The same trend in change in estimated load relative to the SLEUTH planning scenarios that applied to sediment loads is true for nitrogen and this trend is reillustrated for nitrogen loads in Figure 25.

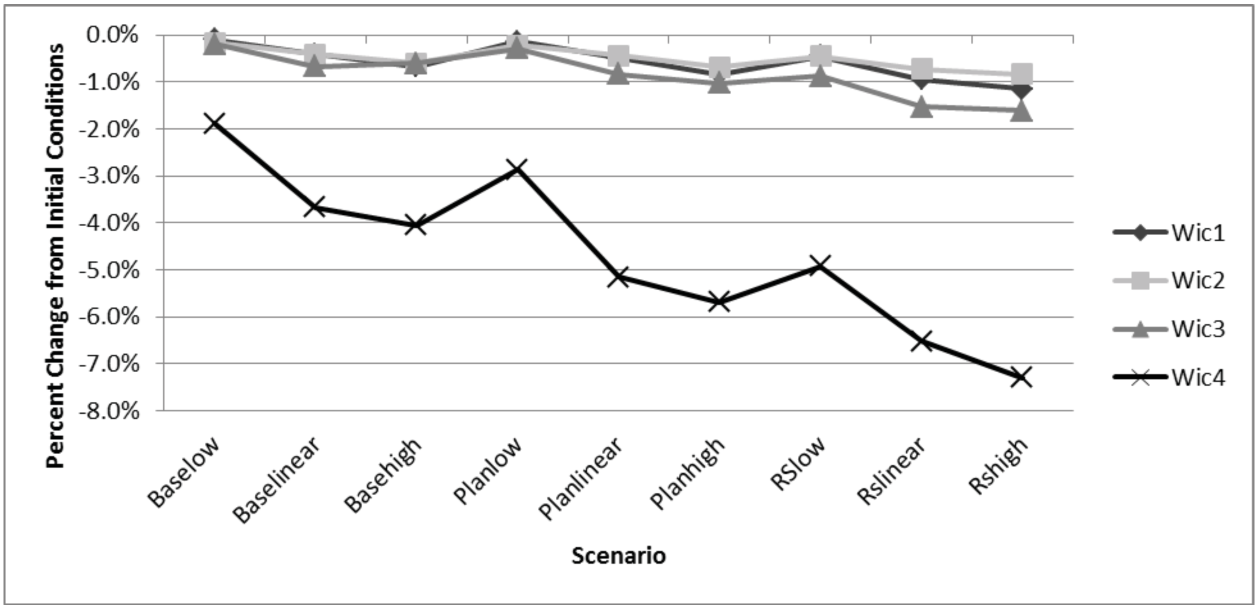

Figure 24. Average Percent Change in Nitrogen Loads from the Initial Land Use Conditions for the Wicomico Watersheds

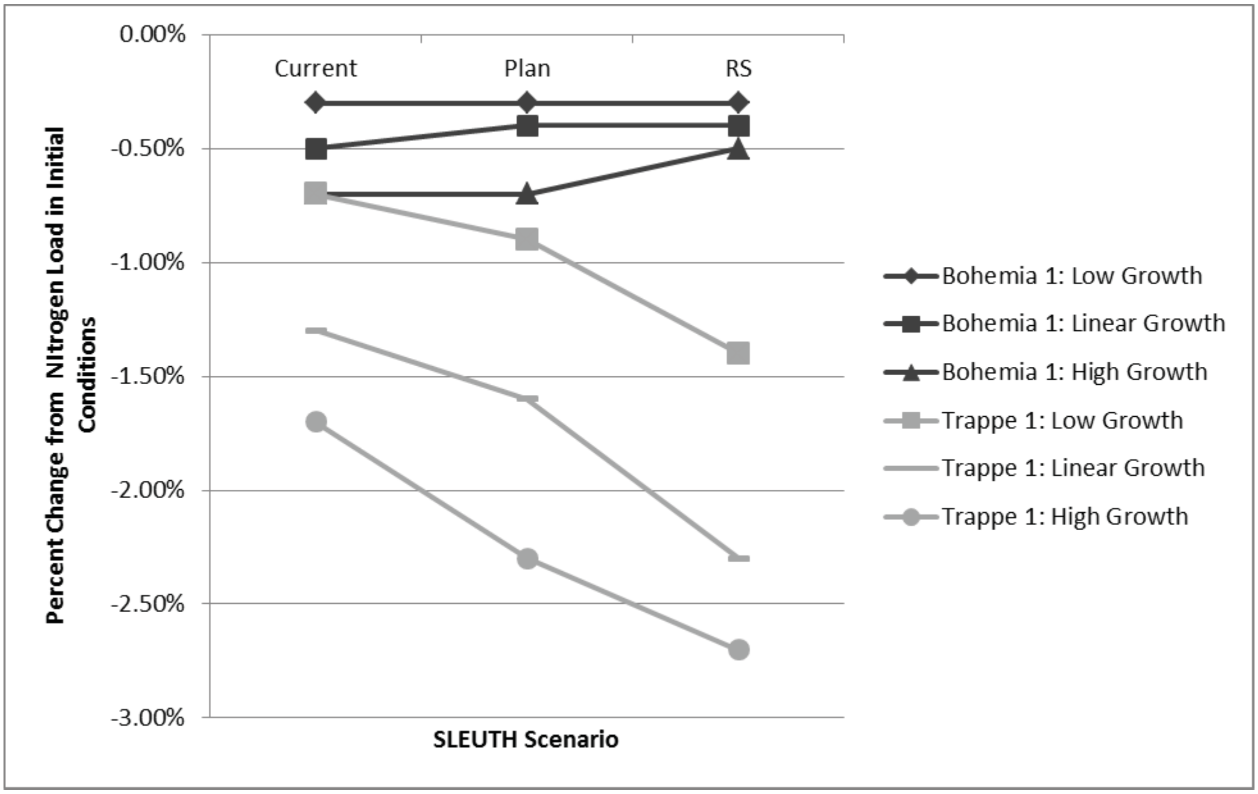

Figure 25. Change in Nitrogen Loads from Initial Land Use Conditions vs. SLEUTH Planning Scenario

Unlike nitrogen and sediment loads, predicted changes in phosphorus loads do not follow easily generalized trends. The Wicomico and Trappe watersheds show decreases in phosphorus when compared to the initial land use conditions loadings ranging from approximately 0% to -7.2%; however the Bohemia and Tred Avon watersheds show increases in phosphorus from 0% to 5.0%. There is also a dichotomy in how the loads change with increased development. Estimated loads for the Wicomico and Trappe watersheds decrease while loads for Bohemia and Tred Avon increase.

To illustrate these two differing patterns, Figure 26 and Figure 27 show changes in phosphorus for the Wicomico and Bohemia watersheds respectively. There are also no clear patterns in how phosphorus estimates change when the SLEUTH planning scenario changes. The Wicomico watersheds tend to show decreasing phosphorus from the current trends scenario to resource scarcity conditions, however the other watersheds have patterns that change with watershed and population growth rate.

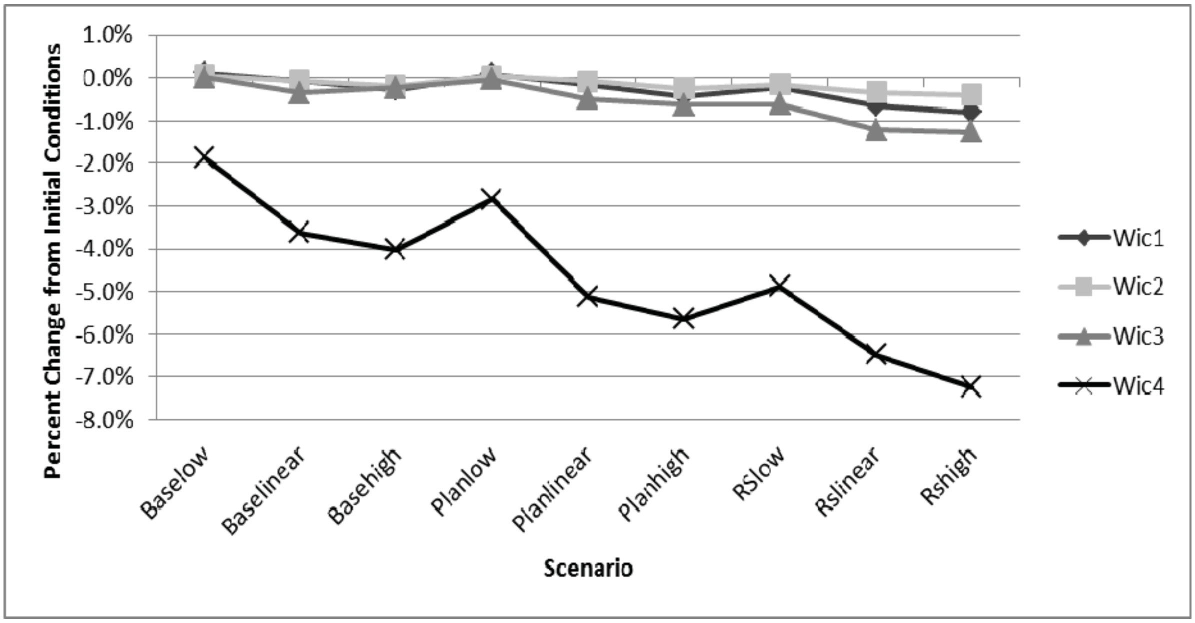

Figure 26. Average Percent Change in Phosphorus Loads from the Initial Land Use Conditions for the Wicomico Watersheds

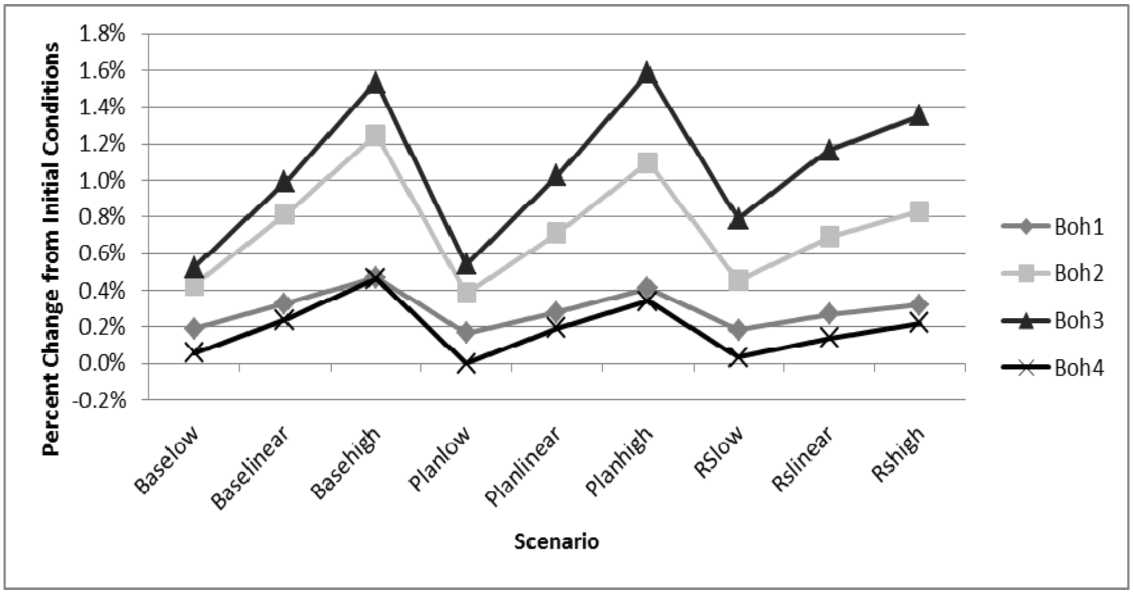

Figure 27. Average Percent Change in Phosphorus Loads from the Initial Land Use Conditions for the Bohemia Watersheds

The results for change in peak flows were much more predictable and reflect the relationship between increased development and imperviousness increasing the composite curve number and thus increasing peak flows. Increased population growth results in increased flows. Flows also increased from the SLEUTH current trends scenario to the resource scarcity scenario as a general rule; however watersheds such as the Bohemia series experienced decreasing flows since total urban land use decreased with increased planning policies in the Bohemia watersheds. Figure 28 and Figure 29 display these trends for the Wicomico watersheds. It also apparent that the amount of change decreases with increasing design storm size. The one major exception in water quantity results is Tred Avon 3a, where the peak flows were predicted to decrease relative to initial land use conditions in all nine of scenarios. The maximum decrease in peak flows from initial conditions is less than 1 percent so the decrease is consistent, but minimal.

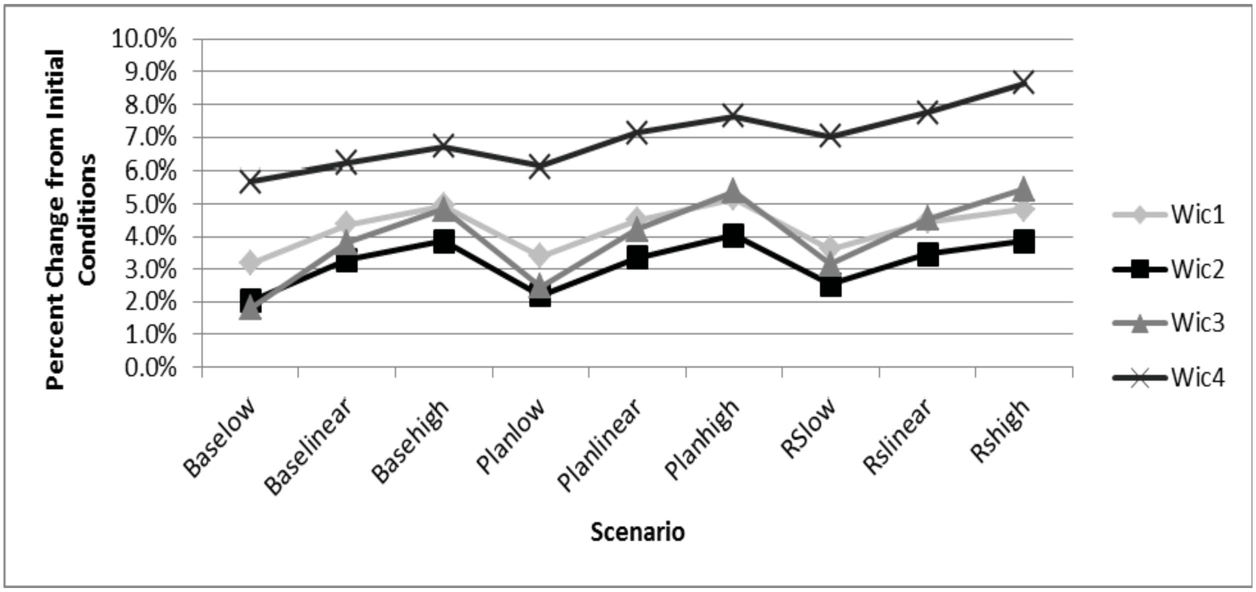

Figure 28. Average Percent Change in the 2-yr, 24-hr Peak Discharge from the Initial Land Use Conditions for the Wicomico Watersheds

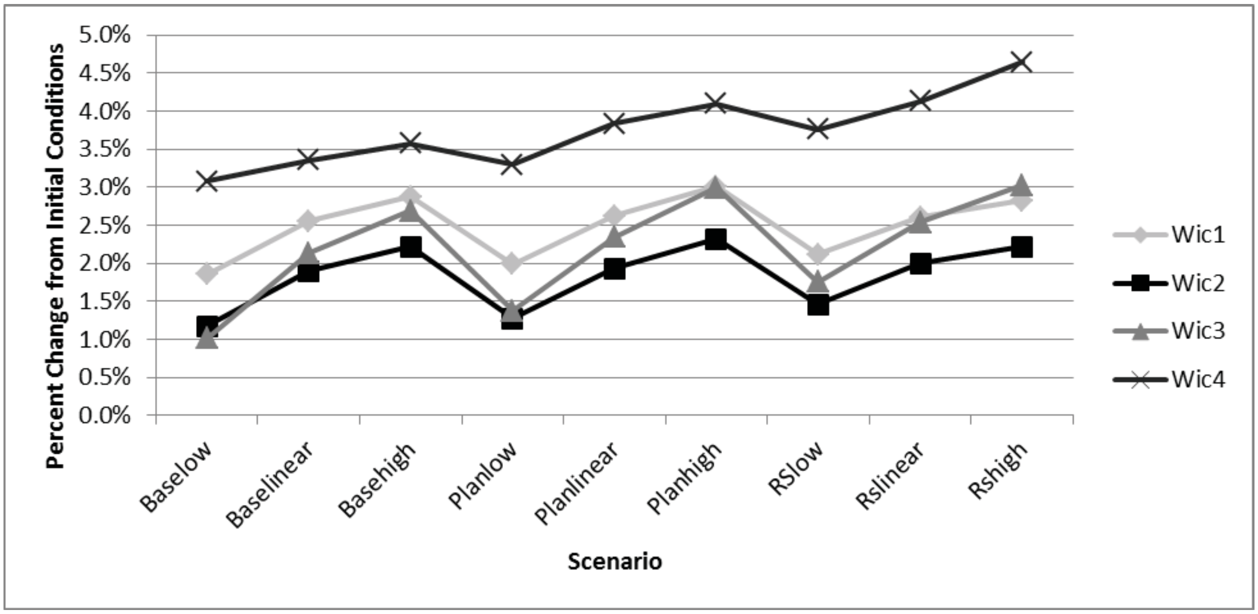

Figure 29. Average Percent Change in the 100-yr, 24-hr Peak Discharge from the Initial Land Use Conditions for the Wicomico Watersheds

3.6 Discussion

The patterns found in the results represent direct consequences from land cover change and vary with both the rate of population growth and the planning and management scenarios. Patterns due to population growth are easy to spot and conceptually simple whereas the patterns due to changes in the base conditions, planning trends, and resource scarcity conditions are more complicated. Changes in land cover from these latter scenarios can be influenced by the specific watershed location and local land conditions as well as differences in implementation of smart growth methods and climate change effects. The resulting hydrologic simulations show the consequences and sometimes benefits of increased land development while suggesting how different land management policies as well as climate change can affect the runoff water quality and quantity that will reach potentially sensitive natural resources such as the Chesapeake Bay.

The relative variations between the 10 realizations for each scenario were evaluated to measure how each realization differed and how this affects the nutrient and flow estimates. Variations were generally small with COVs less than one percent, with the exception of sediment estimates, where the COV still remained below 3 percent. There was noticeably more variation and higher COVs for smaller watersheds and the smaller design storm. This could be expected since smaller values of nutrient loads and peak flows will results in a larger COV for the same amount of change between realizations. This is not strictly true, since variations also depend on the specific changes taking place in each individual watershed, however it is true for most of the watersheds. An example of such an anomaly can be seen in Wicomico 1 which does not always have less variation than Wicomico 2, as it would be expected. New urban growth is attracted to existing urban land in the SLEUTH model so existing urban centers such as those within Wicomico 1 will experience land cover changes which increase variation. Wicomico 2 contains much less urbanization and is thus less susceptible to increases in variation. It is also reasonable to find more variation in the nutrient load values than the peak flow values since changes in flow values depend solely on the amount of urban land added and each realization of a given scenario creates approximately the same amount of urban growth. Nutrient loads are more sensitive to changes between realizations because the most dramatic difference between realizations is the spatial location of urban development which can replace different amounts of land uses, ranging from wetland to forest to agriculture. Depending on which land uses were replaced by urban growth (e.g. forest or agriculture), nutrient loading rates can vary greatly.

Among the nutrient load predictions, sediment loads were found to have the greatest variation. This can be explained by the sediment loading rates which have greater variations between them than phosphorus or nitrogen loading rates.

Within the ten realizations for each scenario, minor differences exist but nothing to suggest considerable differences between realizations. In the final values presented for water quality and quantity predictions, the average of all ten realizations were used since this best represents the findings.

Both nitrogen and sediment loads decreased from the initial land use conditions for all seventeen watersheds and all nine scenarios. The values of sediment and nitrogen loads also decrease with increased growth. Both of these patterns stem from the fact that the estimated loads of both nutrients are consistently decreasing with increased development. This decrease occurs because the CBPO assigns lower loading rates to urban than to agricultural land for both nitrogen and sediment. For example, the Wicomico watersheds lie within state segment 4420, where the nitrogen loading rates for hi till and lot till land use are more than double the loading rates for urban land use. The agricultural loading rates for sediment range from 222 to 1,107 kg/year/hectare whereas urban loading rates are 0.00 to 141 kg/year/hectare. These loading rates are summarized in Table 6.

Table 6. Nitrogen and Sediment Loading Rates (kg/year/hectare) for Segment 4420, which the Wicomico Watersheds Intersect

	Land Use					
Nutrient	**Hi Till**	**Lo till**	**Hay**	**Pasture**	**Pervious Urban**	**Impervious Urban**
Nitrogen	32.25	26.11	11.57	11.28	13.31	10.23
Sediment	1106.95	277.75	221.93	397.90	140.55	0.00

The greatest land use changes taking place is the replacement of agricultural land and forest for urbanized land cover. Although forest has a lower loading coefficient than urban, the loss of sediment loads from agriculture outweighs the loss of forest due to much greater agricultural sediment loading rates and large amounts of farm land in the Delmarva Peninsula that are available for urbanization. Thus it is logical that sediment and nitrogen loads decrease as urban growth, and likewise urban land use, increases.

Expected sediment and nitrogen loads were found to both decrease and increase with changes in the planning scenarios depending on the watershed as well as the growth scenario. In both Wicomico and Trappe watersheds sediment and nitrogen loads generally decreased from current trends to planning trends and from planning trends to resource scarcity conditions. However in Tred Avon and Bohemia watersheds it was often the case that, particularly for high growth circumstances, sediment loads would actually increase from current trends to planning trends and from planning trends to resource scarcity conditions. This finding is caused by the corresponding trends in urban land use change from current trends to resource scarcity. In watersheds such as Wicomico 1 and Trappe 1, urban land use increases from current trends to planning trends and from planning trends to resource scarcity conditions causing decreases in sediment and nitrogen loads. The amounts of urban growth in the planning trends and resource scarcity scenarios are also likely to change based on the specific location and existing urbanization of a study area, since smart growth policies tend to focus increased developed land around existing urban centers and discourage urban sprawl. So an existing urbanized watershed may experience greater urbanization in the planning trends and/or resource scarcity than in the base conditions due to relocation of urban land that would otherwise be more dispersed.

Phosphorus predictions result in a divide between Tred Avon and Bohemia vs. Wicomico and Trappe watersheds. The latter experience decreases in predicted phosphorus when compared to initial conditions and decreasing phosphorus with increasing population growth while the former experience the opposite result. Understanding these phenomena requires a more detailed look at the loading rates used to estimate nutrient runoff. Phosphorus loading coefficients are less variable in magnitude than those of nitrogen and sediment. Agricultural land uses, and most specifically, hi till land, has much higher nutrient loading coefficients than urban land uses. Nitrogen and sediment loading rates generally decrease on a spectrum from hi till, low till, pasture, hay, urban land, non-agricultural open, and forest land uses. This creates a logical decrease in the nutrient loading in most of the highly agricultural watersheds in the Delmarva Peninsula when urban land uses increase. What ultimately creates this divide in whether phosphorus loads increase or decrease for a particular realization is the relative amount of lo till land and forest removed vs. the amount of hi till land. Pervious urban land has loading rates that are smaller than hi till land but larger than low till land. Since the majority of developed land is assigned to pervious urban land, these loading rates have a larger effect on the overall urban phosphorus load. When phosphorus loads are found to decrease in the 2030 predictions, this is generally due to enough hi till land being removed and replaced with pervious urban that the amount of phosphorus removed is too great to be counter-balanced by phosphorus being added by the urban land. When phosphorus loads are increasing in SLEUTH predictions as in the Tred Avon and Bohemia watersheds, these watersheds are losing less hi till land and often are losing lo till farm land.

Although decreases in nutrient loads from increased development may be initially counterintuitive, these numbers are supported by the loading rates used in the calculations as well as a recent study done by Roberts et al. which predicts decreases in both phosphorus and nitrogen due to losses of agricultural land in the Chesapeake Bay by 2030. (2009) Other recent findings cite that agricultural lands is one of the greatest sources of annual nitrogen loads (Shields et al. 2008) and is largest contributor to nitrogen and phosphorus loadings in the Chesapeake Bay (Goetz et al. 2004; Roberts et al. 2009; Najjar et al. 2010) thus consistent with the results presented in this work.

Increased urban land cover and imperviousness results in higher peak flows with most flow increases ranging from less than 1 percent up to about 9 percent. This is logical since increased impervious cover increases curve numbers, which in turn decreases times of concentration and base flows. Smaller watersheds are even more prone to increases in flow because they are more sensitive to smaller changes in land cover and raised curve numbers.

However Tred Avon 3a behaves differently in an unusual case where the peak flows actually decreased in all of the predicted scenarios in comparison to the 2005 flows. First, it must be noted that the decreases are small and reach a maximum increase of 0. 2 m^3/s or 0.8 percent in a 8 km^2 watershed. Secondly, this decrease, although peculiar, is due to an unusually large amount of C-CAP land cover “cultivated crops” being developed. In one realization of the base linear scenario, SLEUTH predicted that more than 65 percent of the land being developed in the Tred Avon 3a watershed is cultivated crops. Cultivated crops are unique because the curve numbers can often be higher than developed land. In the case of Tred Avon 3a, the crops that were replaced by developed land had a higher curve number than the urban land replacing it and thus the overall peak flows actually increased, although only slightly.

Within the processes used to make land cover, water quality, water quantity predictions lies the potential for methodological errors that can decrease accuracy. These include necessary assumptions used in modeling land cover changes, errors in the nutrient and discharge models and decisions made in the land cover conversion processes.

The first and most basic of weaknesses lies in the land cover data itself. SLEUTH combines all of the C-CAP urban land cover categories into one urban category, which then must be reconverted to the more detailed urban categories in the CBPO land cover classification system. This compounds the inherent, but unavoidable weakness in rasterized land cover data is that it can understate the true heterogenic nature of land cover (Nilsson et al. 2003). Although it is felt that these conversions capture the necessary characteristics of the type of land cover necessary to compare the magnitude of *change* in a watershed, there are unavoidable losses in accuracy that will be more noticeable on smaller study areas. Ideally, the classification system for land cover would remain consistent in all stages of the modeling process.

Inherent in any model is the simplification of a real system in an attempt to gain a reasonable understanding it. The SLEUTH model successfully captures a number of factors influencing the type and amount of urban development, especially with growth estimates provided by PED. However the model excludes any way of accounting for major economic and social factors which tend to affect development at more local and regional scales. The same simplifications are found in TR-20 and the CBPO method, which do not model detailed biological and hydrological processes. Both TR-20 and SLEUTH are well established and provide reliable results that can rather accurately describe the magnitude of change in water quality and quantity, if not the absolute amounts. The CBPO model is more prone to error since it has been found to calculate nutrient loading rates using erroneous methods (Shivers and Moglen 2008). However, these flawed loading rates can still provide a reasonable estimate of how nutrient loads will differ from those in 2005, even if the values themselves are incorrect.

3.7 Conclusions

This study took a unique approach to understanding some of the changes in water quality and water quantity that will occur in the near future due to changing population growth rates, land management and planning decisions as well as rising sea levels. The future holds any combination of these different factors and this study shows the resulting range of consequences that will affect natural resources in the Delmarva Peninsula as well as sensitive environmental areas downstream such as the Chesapeake Bay. The SLEUTH model combines its ability to create cellular automaton predictions of land cover with the PED model, which predicts total land development based on population growth. The 10 SLEUTH realizations were analyzed for a low, linear, and high population growth scenario for all three planning scenarios: a current trends scenario, a planning trends scenario, and a resource scarcity scenario.

The 90 rasterized predictions of urbanization created by SLEUTH were used as inputs to determine the resulting changes in peak discharge and nutrient loads resulting from these changes in land use. Both the CBPO model and TR-20 provide general estimates which allow comparison between consequences from different scenario assumptions.

The results generally reflect that increased population growth results in increased development and imperviousness. This then caused sediment and nitrogen loads to decrease by up to 8 percent and 37 percent respectively within the study areas. However these maxima reflect more extreme changes in smaller watersheds. Unlike sediment and nitrogen, phosphorus responded differently to increased development depending on what type of existing land cover was replaced by urban land cover.

Peak discharge estimates generally reflected moderate increases due to the increases in imperviousness caused by increased development, with one exception. In one of the smaller watersheds, the amount of cultivated cropland predicted to be replaced by developed land was large enough that the composite curve number for the watershed actually decreased from the initial conditions. Cultivated crops have relatively high curve numbers that are higher than some urban land cover curve numbers. This results, although strange, shows how individual watersheds, especially smaller ones, may not follow general trends due to unique or rare conditions within the watershed. At larger regional scales, these exceptions do not occur.

Examining trends between base, planning and resource scarcity conditions did not provide any conclusive trends. In some watersheds there were sharp decreases in nutrient loads and/or peak flows as planning policies and stricter conservation efforts were applied in the planning trends and resource scarcity scenarios. However, results varied greatly and it was common to see an increase in nutrient load or peak flow from the planning trends scenario to the resource scarcity scenario. Further exploration revealed that these increases were due to corresponding increases in urban development between the two scenarios. Thus we conclude that these planning measures can help mitigate the effects of land development, but must be evaluated in each individual watershed to fully understand what the consequences of these measures will be.

The predictions generated in this study estimate land cover change in the Delmarva Peninsula by the year 2030 will decrease sediment and nitrogen loads, increase peak runoff flows, and result in variable changes in phosphorus depending on the relative mixture of hi till vs. low till farm land which is removed. Our study is the first to combine SLEUTH, PED, and GIS-based analysis to understand the effects of urban development and can provide a useful method for evaluating future planning and management decisions within a desired region.

Chapter 4: Conclusions

4.1 Conclusions

Decision makers throughout the Delmarva Peninsula benefit from tools that allow them to forecast land use change so they can plan for the resulting future changes to water quality and quantity. This study quantifies some of the changes in water quality and water quantity that can occur in the near future due to changing population growth rates, land management and planning decisions. The future holds any combination of these different factors and this study shows the resulting range of consequences that will affect natural resources in the Delmarva Peninsula as well as sensitive environmental areas downstream such as the Chesapeake Bay. The SLEUTH model combines its ability to create cellular predictions of land cover with PED, which predicts total land development based on population growth. The 10 SLEUTH realizations were analyzed for a low, linear, and high population growth scenario for all three planning scenarios: a current trends scenario, a planning trends scenario, and a resource scarcity scenario.

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4.2 Recommendations for Future Research

The methods used to here to create a tool for examining water quality and quantity are just one step towards creating more accurate and realistic models of land cover change and its hydrological and environmental effects. SLEUTH is an evolving model which could more accurately predict land cover changes if more detailed inputs were added or changes to the model’s methodology were made. Additions to this model could include modeling development density as well as microeconomic forces such as property values, local zoning regulations and property taxes.

The Chesapeake Bay Program Office continues to update their watershed model, potentially providing more accurate land cover and nutrient loading rates. Increased water quality data collection could be used to calibrate more accurate loading estimates used to calculate the loading rates. It would be worthwhile to further study the likelihood of some of the predicted results which are counter intuitive. This study suggests that additional development has the potential to decrease nutrient loads and even decrease peak flows in certain circumstances. If this happens in real systems, it would mean that additional development, when strategically located, could actually improve water quality and quantity. Future studies could address the likelihood of this as well as experimenting with the optimal location for future development.

This model could also be used to analyze other water quality indicators such as change in water temperature, organic matter, or heavy metals. Every effect of land use changes should be understood so that the proper planning decisions can be made.

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Appendices

Appendix A. Land Cover Conversion Process

The first step in determining total CBPO land use was to clip each of the C-CAP and NLCD land cover layers to every study watershed using GIS. They were then clipped again to each CBPO cosegment within each watershed. Once the amounts of C-CAP and NLCD land cover within each cosegment in each watershed is known, the C-CAP data can be converted to CBPO land cover, which can easily be converted to CBPO land use as required to estimate CBPO nutrient loadings. NLCD land cover is included in the land cover conversion process because SLEUTH output only assigns urban land to one generic category that needs to be converted into four different gradations of urban land in the CBPO land cover categorization. NLCD data is used to assign different levels of urbanization to SLEUTH's generic urban land category as well as maintain the existing amount of high, medium, and low density development that exists in the NLCD data.

Conversion from SLEUTH output Land Cover Classes (C-CAP) to the Chesapeake Bay Program Land Use (CBPLU)

To analyze changes in water quality and nutrient loads, land cover classified within the CBPO classification system is converted to land use so that nutrient loading coefficients developed by the CBPO can be applied. However in the case of urban/ developed land, it was necessary to first convert the C-CAP land cover to the National Land Cover Dataset (NLCD) before it can be converted to CBPO, since the NLCD data set covers the entire Delmarva Peninsula, not just parts within the Chesapeake Bay watershed.

To elucidate this process, a worked numerical example can be found in Appendix B. As a reference, Table 7, Table 8, and Table 9 list each land cover category and description within the three land cover classification systems which are used.

Table 7. SLEUTH's output of C-CAP Land Cover

	#	Description
Uplands	1	Developed, High Intensity
	2	Developed
	3	Developed, Medium Intensity
	4	Developed, Low Intensity
	5	Developed, Open Space
	6	Cultivated Crops
	7	Pasture/Hay
	8	Grassland/Herbaceous
	9	Deciduous Forest
	10	Evergreen Forest
	11	Mixed Forest
	12	Scrub/Shrub
	13	Palustrine Forested Wetland
	14	Palustrine Scrub/Shrub Wetland
Wetlands	15	Palustrine Emergent Wetland (Persistent)
	16	Estuarine Forested Wetland
	17	Estuarine Scrub/Shrub Wetland
	18	Estaurine Emergent Wetland
	19	Unconsolidated Shore
	20	Barren Land
	21	Open Water
	22	Palustrine Aquatic Bed

Table 8. NLCD Land Cover Descriptions

#	Description
11	Open Water
21	Developed, Open Space
22	Developed, Low Intensity
23	Developed, Medium Intensity
24	Developed, High Intensity
31	Barren Land
41	Deciduous Forest
42	Evergreen Forest
43	Mixed Forest
81	Pasture/Hay
82	Cultivated Crops
90	Woody Wetlands
95	Emergent Herbaceous Wetlands

Table 9. CBPO Land Cover Descriptions

#	Description
11	High Intensity Urban (HIU)
12	Low Intensity Urban (LIU)
13	Herbaceous Urban (HU)
14	Woody Urban (WU)
20	Herbaceous
30	Woody
40	Exposed
60	Water
70	Herbaceous Wetlands

Non-Urban Land Cover Conversion

The following non-urban C-CAP classification categories are mapped as shown in Table 10 from C-CAP to CBPO land cover classes. These classifications were based on the descriptions of each C-CAP Land Cover category described at www.csc.noaa.gov/crs/lca/tech_CIS.html

(NOAA Coastal Services Center 2009) as well the CBPO Land Uses to which each CBPO Land Cover class contributes.

Table 10. Conversion from C-CAP to CBPO Land Cover for Non-Urban Land Types

#	**C-CAP Land Cover**		**CBPO Land Cover**
6	Cultivated Crops	=	20 Herbaceous
7	Pasture/Hay	=	20 Herbaceous
8	Grassland/Herbaceous	=	20 Herbaceous
9	Deciduous Forest	=	30 Woody
10	Evergreen Forest	=	30 Woody
11	Mixed Forest	=	30 Woody
12	Scrub/Shrub	=	30 Woody
13	Palustrine Forested Wetland	=	30 Woody
14	Palustrine Scrub/Shrub Wetland	=	70 Herbaceous Wetland
15	Palustrine Emergent Wetland (Persistent)	=	70 Herbaceous Wetland
16	Estuarine Forested Wetland	=	30 Woody
17	Estuarine Scrub/Shrub Wetland	=	70 Herbaceous Wetland
18	Estaurine Emergent Wetland	=	70 Herbaceous Wetland
19	Unconsolidated Shore	=	40 Exposed
20	Barren Land	=	40 Exposed
21	Open Water	=	60 Water
22	Palustrine Aquatic Bed	=	70 Herbaceous Wetland

It should also be noted that C-CAP Land cover categories 13 and 16 (Palustrine Forested Wetland and Estuarine Forested Wetland) were chosen to be converted to the CBPO Woody Land Cover category (30) because the original CBPO determination of these Land Cover categories, Deciduous, Evergreen, and Mixed Forest Wetland were likewise converted to the Woody Land Cover class (Hopkins et al. 2000). Since the Chesapeake Bay Program has previously decided that the woody component of this land cover should supersede the wetland component, this idea was upheld for consistency. Also, as shown below, whether classified as Herbaceous Wetland or Woody, ultimately, both would be reclassified as Forest land use. Table 11 lists the CBPO land use categories which each land cover classification can be mapped into during nutrient analysis:

Table 11. Possible CBPO Land Uses Each CBPO Land Cover Can Be Assigned

CBPO Land Cover		CBPO Possible Land Uses
#	Description	Description
11	High Intensity Urban (HIU)	Impervious Urban, Pervious Urban
12	Low Intensity Urban (LIU)	Impervious Urban, Pervious Urban
13	Herbaceous Urban (HU)	Impervious Urban, Pervious Urban
14	Woody Urban (WU)	Impervious Urban, Pervious Urban
20	Herbaceous	Lo Till, Hi Till, Pasture, Hay, Manure, Non-Agricultural Herbaceous
30	Woody	Forest
40	Exposed	Impervious Urban, Pervious Urban
60	Water	Water
70	Herbaceous Wetlands	Forest

Urban Land Cover Conversion

With the other C-CAP/SLEUTH land cover classes converted to CBPO, the only remaining classes which must be converted to CBPO are the SLEUTH “developed” land cover categories, 1 through 5. These must be converted to CBPO land cover categories: High Intensity Urban (11), Low Intensity Urban (12), Herbaceous Urban (13), and Woody Urban (14).

To preserve existing amounts of urban land cover and their respective intensities, the SLEUTH output is overlain with the existing NLCD and these amounts of urban cover are preserved with the assigned NLCD urban land cover categories. NLCD urban land covers include: Developed Open Space (21), Developed Low Intensity (22), Developed Medium Intensity (23) and Developed High Intensity (24).

Upon numerically removing the tabulated amount of existing NLCD urban which overlaps the SLEUTH developed, the remaining urban SLEUTH land cover, which has not been classified as one of the four NLCD urban land cover categories, must also by classified as such.

As shown in Table 7, classes 1, 3, 4, and 5 are developed land cover categories with varied and specified intensities. Due to modeling methods incorporated in the SLEUTH land cover prediction process, the SLEUTH output contains a number of areas classified as non-urban land cover, which are categorized as urban (categories 1,3,4 or 5) in the existing C-CAP land cover. So, in an effort to maintain the latest recorded amount of developed land cover, these areas will maintain their developed land cover designations. To convert areas such as these to CBPO land cover, they are first assigned the corresponding NLCD land cover category since there are direct parallels between C-CAP and NLCD land cover descriptions. Table 12 shows this intermediate conversion.

Table 12. Direct Conversion from C-CAP Urban Land Cover to NLCD Urban Land Cover Categories

#	**SLEUTH's output of C-CAP Land Cover**		#	**NLCD Land Cover**
1	Developed, High Intensity	=	24	Developed, High Intensity
3	Developed, Medium Intensity	=	23	Developed, Medium Intensity
4	Developed, Low Intensity	=	22	Developed, Low Intensity
5	Developed, Open Space	=	21	Developed, Open Space

The other developed category, or "2", will have to be converted to NLCD land cover categories as well. This is done based on the existing percentages of NLCD Urban land cover categories within each cosegment. Note that it would be possible to convert the SLEUTH developed land cover directly to CBPO land cover using the same concept of existing percentages of urban cover within each cosegment. However, CBPO land cover only exists in parts of the Delmarva Peninsula which drain to the Chesapeake Bay. So the model can be applied throughout the entire Delmarva Peninsula, all SLEUTH developed land cover will be converted to CBPO land cover using the existing NLCD data.

Once the SLEUTH urban/developed land cover is converted to NLCD developed land cover classes, these then must be converted to CBPO land cover so that they can ultimately be converted to a CBPO land use. This will be done using the following conversions in Table 14. These numbers are based on analyses of how the existing CBPO land cover (Chesapeake Bay

Program 2006) urban classes compare to urban land cover categories in the NLCD data set as shown in Table 13. The data in Table 13 shows the raster cell count of how many cells of each type of CBPO urban land cover intersect each cell of NLCD developed land cover. This applies to any area where NLCD data intersect CBPO land cover data, which is essentially the Chesapeake Bay watershed within the Delmarva Peninsula as well as parts east and south of the peninsula in Maryland and Virginia.

The percentages shown in Table 13 quantify the portions of the total area in which CBPO urban and NLCD urban overlap which is made up of each type of CBPO urban cover. Using these raw data, Table 14 was developed as the conversion table which will be used to convert NLCD urban to CBPO urban land cover. In the cases of NLCD "developed, open space" and "developed, medium intensity", both are made up of all four NLCD urban classes. However, when the percentage of CBPO land within the overall NLCD class fell at or below 10 percent, we felt that this intersection of land cover groups was trivial and could be omitted in the final conversion. Note that in Table 14, the conversions for open space and medium intensity both include only two of the four possible CBPO urban classes. Finally, both NLCD "developed, low intensity" and "developed, high intensity" are converted directly to their categorical equivalents since the vast majority of both (75% or greater) matched their corresponding CBPO classification.

Table 13. Breakdown of Overlap Between How Existing Developed CBPO Land Cover and Existing Developed NLCD Land Cover Categories (as of 2005)

NLCD Land Cover	CBPO Herb Urban	%	CBPO High Urban	%	CBPO Low Urban	%	CBPO Woody Urban	%	Total
Developed, Open Space	173,430	41%	9,570	2%	196,144	46%	43,665	10%	100%
Developed, Low Intensity	45,150	13%	29,720	8%	268,430	76%	11,869	3%	100%
Developed, Medium Intensity	16,788	8%	81,939	41%	98,449	49%	2,860	1%	100%
Developed, High Intensity	4,335	4%	85,512	82%	14,215	14%	669	1%	100%

Table 14. Finalized Conversion from NLCD Developed Land Cover to CBPO Developed Land Cover Categories

NLCD Land Cover		CBPO Land Cover
Open Space	=	47 % Herbaceous Urban & 53 % Low Intensity Urban
Low Intensity	=	Low Intensity Urban
Medium Intensity	=	46% High Intensity Urban & 54% Low Intensity Urban
High Intensity	=	High Intensity Urban

Figure 30 shows a visual representation of the entire conversion process.

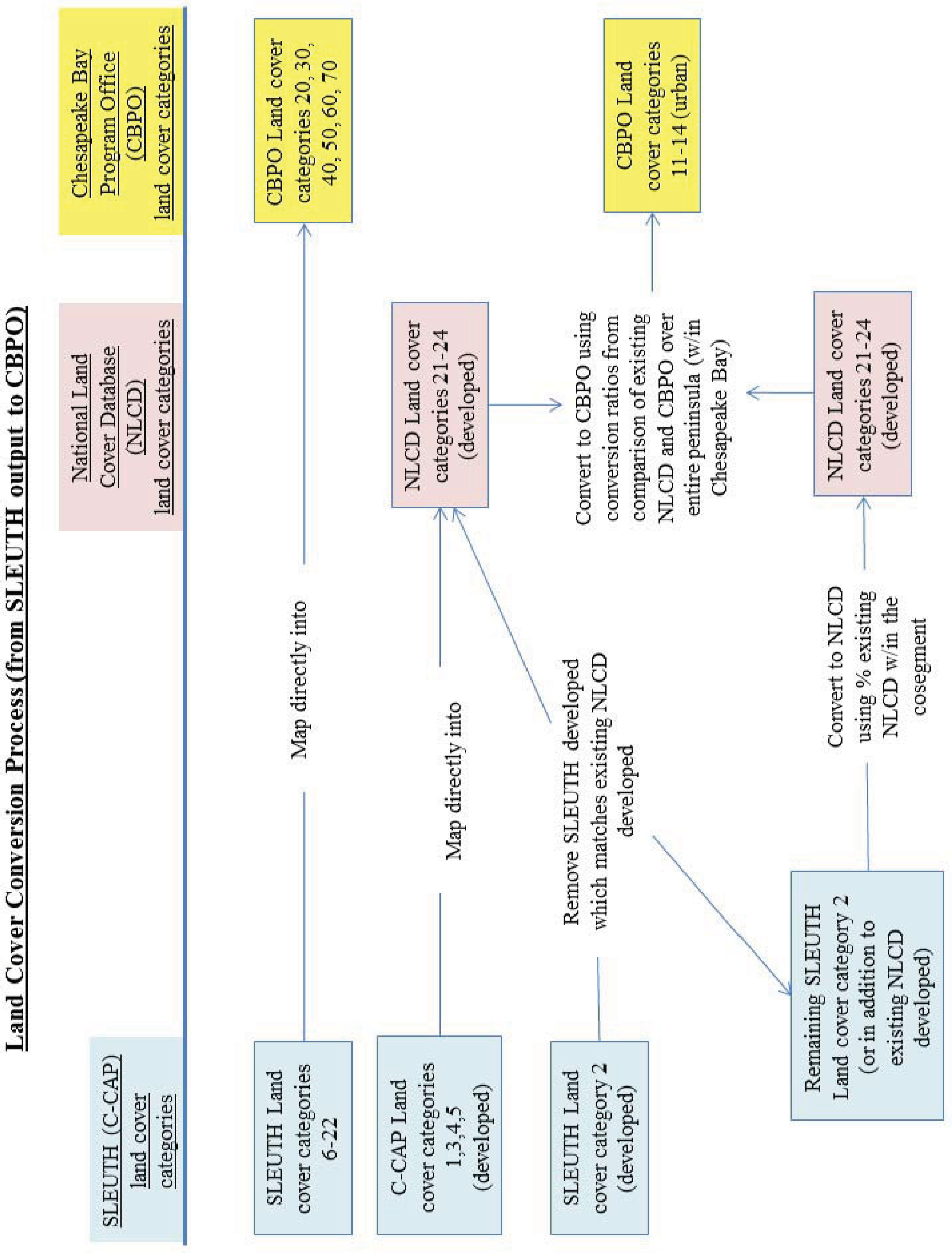

Figure 30. Flow Chart for the Land Cover Conversion Process

Appendix B. Worked example of Conversion from SLEUTH output to CBPO Land Use

Tables 15 through 17 show the results from GIS analysis of the SLEUTH land cover prediction for the Wicomico 1 watershed for the first (or zero) realization of the baselinear scenario for the portion which is within cosegment 420024045.

Table 15. Baselinear0 land cover within Wicomico 1 within Cosegment 420024045

VALUE	COUNT
1	49
2	58,390
3	172
4	1,042
5	21,625
6	69,313
7	15,516
8	2,367
9	14,603
10	16,615
11	13,073
12	12,901
13	30,378
14	2,160
15	748
18	261
19	23
20	143
21	1,820
22	11

Table 16. Initial land cover conditions within Wicomico 1 within Cosegment 420024045

VALUE	COUNT
1	7,524
2	4,291
3	10,749
4	19,721
5	21,630
6	77,410
7	16,008
8	2,875
9	16,189
10	17,729
11	14,356
12	15,749
13	31,699
14	2,183
15	755
18	268
19	34
20	200
21	1,829
22	11

Table 17.NLCD land cover within Wicomico 1 within Cosegment 420024045

VALUE	COUNT
11	1,262
21	17,403
22	17,057
23	9,036
24	5,211
31	4,507
41	47,957
42	19,147
43	8,584
81	42,004
82	82,229
90	3,435
95	3,417

The first step is to make the direct conversions from C-CAP (SLEUTH) to CBPO as shown in Table 18.

Table 18. Baselinear0 Wicomico 1 Within Cosegment 420024045Results with Non-Urban C-CAP Values Converted to CBPO Land Cover

VALUE	COUNT
1	49
2	58,390
3	172
4	1,042
5	21,625
20	87,196
30	87,570
40	166
60	1,820
70	3,180

Then the existing NLCD developed cells are subtracted from the SLEUTH developed class "2" and the other developed cells from the SLEUTH output (categories 1,3,4,5) are added to this total as shown in Table 19.

Table 19. Calculation of SLEUTH Urban Areas that Need to be Classified using Existing NLCD Urban Land Cover within the Cosegment

SLEUTH Urban (2) within AOI		**Existing NLCD**			**Other SLEUTH developed categories (1,3,4,5)**			**Remaining SLEUTH urban within AOI to be classified**
58,390	-	21	17,403	+	1	49	=	32,571
		22	17,057		3	172		
		23	9,036		4	1,042		
		24	5,211		5	21,625		
		Total:	48,707		Total:	22,888		

Then the 32,549 cells of SLEUTH developed land will be assigned NLCD developed land cover classes by using the same proportions of each developed class of NLCD within the cosegment. First, these proportions are derived from the output (Table 20).

Table 20.NLCD Urban within Cosegment 420024045

#	# Cells	% of total Urban
21	20,206	38%
22	18,616	35%
23	9,382	17%
24	5,266	10%

Then these are applied to the 32,549 remaining cells (Table 21).

Table 21. Remaining SLEUTH Urban Land Cover Assignment to NLCD Developed Categories

LC	# Cells	% of total urban
21	12,308	38%
22	11,340	35%
23	5,715	17%
24	3,208	10%
Total:	32,571	

Now these cells are combined with the existing NLCD developed land cells which were previously removed from total amount of developed land cover cells to find the total amount of NLCD developed land cover within Wicomico 1 in this particular cosegment (Table 22).

Table 22. Completed Conversion from C-CAP/SLEUTH Developed Categories to NLCD Developed Categories

#	NLCD based on %'s		Existing NLCD		Total NLCD developed cells
21	12,308		17,403		29,711
22	11,340	+	17,057	=	28,397
23	5,715		9,036		14,751
24	3,208		5,211		8,419
Total:	32,571		48,707		81,278

Finally, these categories are converted to CBPO developed land cover categories using the conversion table presented in Table 13 which is shown in Table 23.

Table 23. Conversion from NLCD Developed Categories to CBPO Land Cover

				New CBPO Land Cover Class		
NLCD Land Cover		Conversion to CBPO Land Cover		HU	LIU	HIU
21	=	47 % Herbaceous Urban & 53 % Low Intensity Urban	-->	13,964	15,747	0
22	=	Low Intensity Urban	-->	0	28,397	0
23	=	46% High Intensity Urban & 54% Low Intensity Urban	-->	0	7,966	6,785
24	=	High Intensity Urban	-->	0	0	8,419
			Total:	13,964	52,109	15,204

The final result and reclassification to the CBPO land cover classification system of the area of interest is shown in Table 24.

Table 24. Final Tabulated CBPO Land Cover

VALUE	Description	COUNT
11	High Intensity Urban (HIU)	15,204
12	Low Intensity Urban (LIU)	52,109
13	Herbaceous Urban (HU)	13,964
14	Woody Urban (WU)	0
20	Herbaceous	87,196
30	Woody	87,570
40	Exposed	166
60	Water	1,820
70	Herbaceous Wetlands	3,180

Appendix C. Remaining Watersheds Location Maps

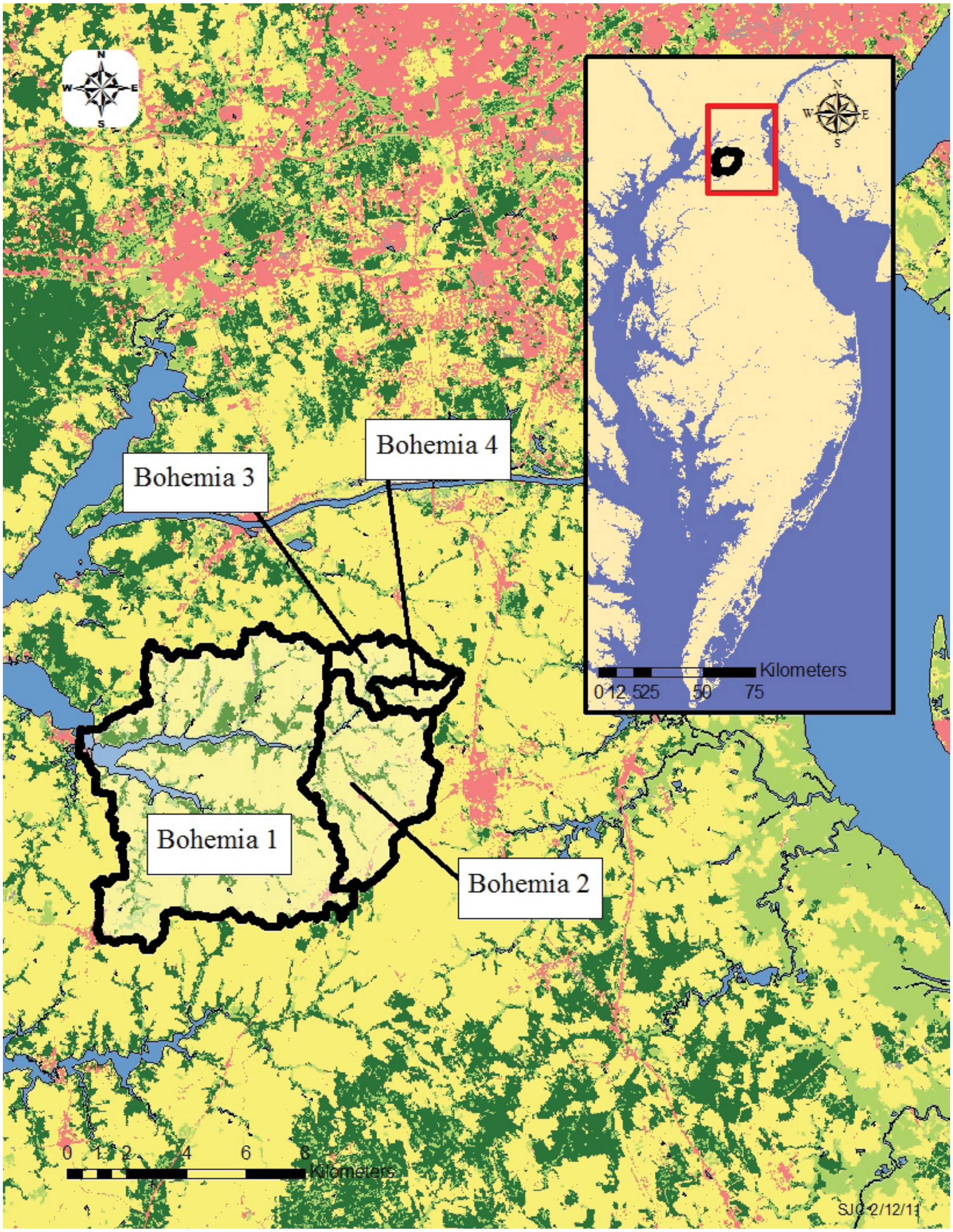

Figure 31. Location of the Bohemia River Watersheds

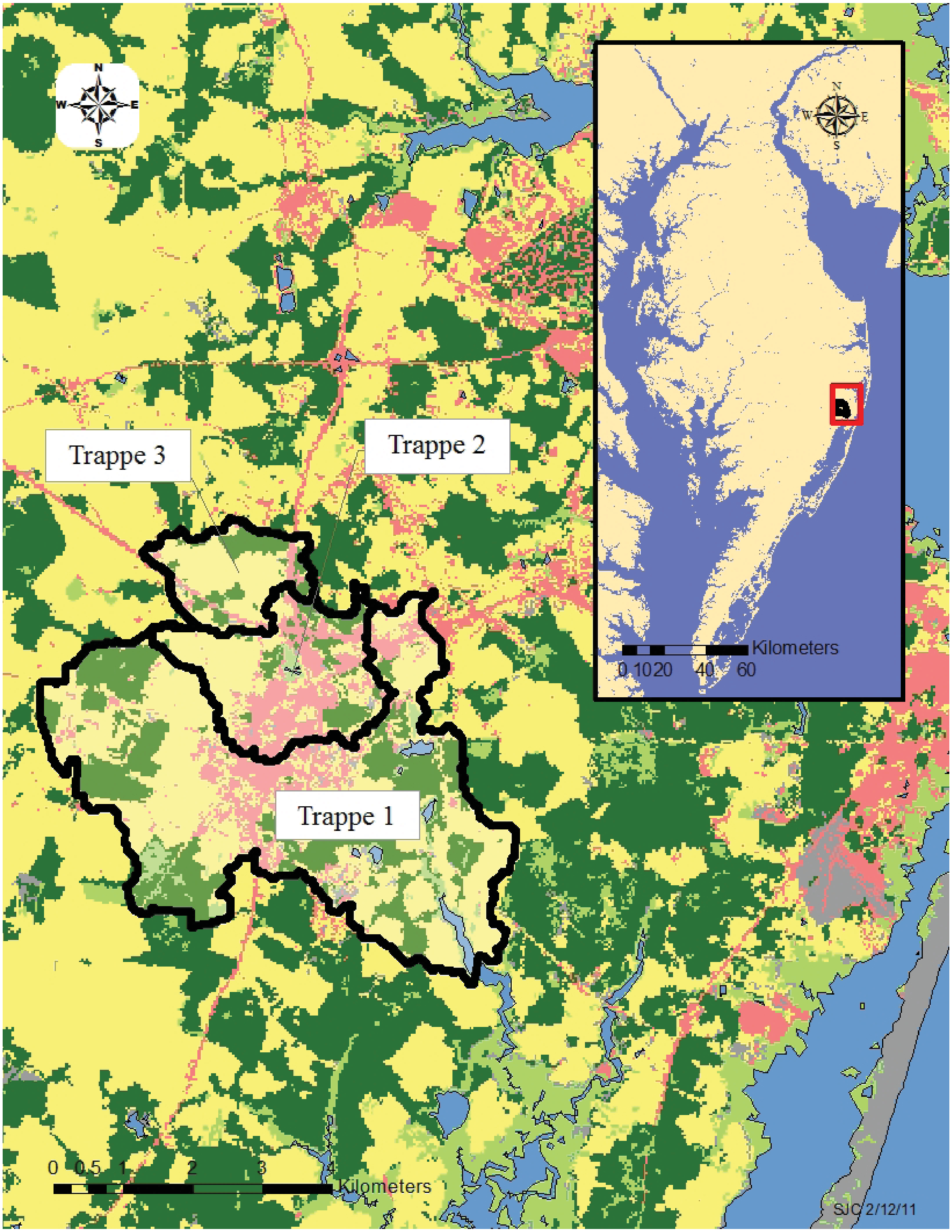

Figure 32. Location of the Trappe Creek Watersheds

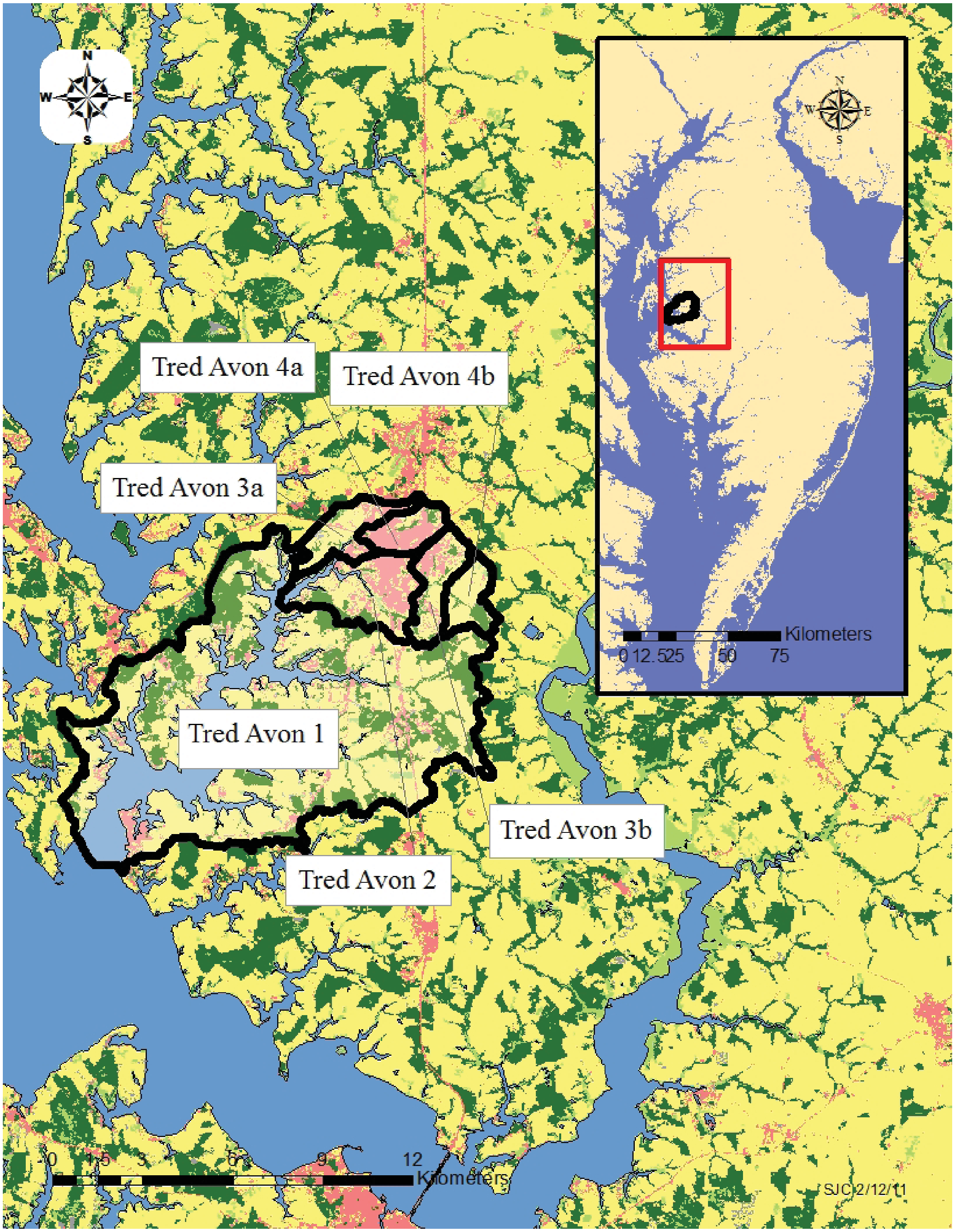

Figure 33. Location of the Tred Avon River Watersheds

Appendix D. Tabulated CBPO Land Use and Land Use Change

Table 25. Tabulated CBPO Land Use for the Bohemia River Watersheds

		CBPO Land Use (sq. km)										
		Hi Till	**Lo Till**	**Pasture**	**Hay**	**Non Ag**	**Manure**	**Impervious Urban**	**Pervious Urban**	**Forest**	**Water**	**Total**
Boh1	**Initial Conditions**	13.56	21.26	7.41	4.89	21.12	0.02	1.44	2.71	17.87	0.61	90.88
	Baselow	13.37	21.02	7.36	4.85	20.94	0.02	1.69	3.18	17.84	0.61	90.88
	Baselinear	13.23	20.85	7.34	4.82	20.82	0.02	1.87	3.51	17.82	0.61	90.88
	Basehigh	13.06	20.65	7.31	4.80	20.69	0.02	2.07	3.86	17.80	0.61	90.88
	Planlow	13.39	21.04	7.37	4.85	20.95	0.02	1.67	3.13	17.85	0.61	90.88
	Planlinear	13.27	20.90	7.35	4.83	20.86	0.02	1.81	3.40	17.83	0.61	90.88
	Planhigh	13.10	20.70	7.32	4.81	20.73	0.02	2.01	3.76	17.82	0.61	90.88
	RSlow	13.36	21.01	7.36	4.85	20.93	0.02	1.70	3.19	17.85	0.61	90.88
	Rslinear	13.26	20.89	7.35	4.83	20.85	0.02	1.81	3.41	17.84	0.61	90.88
	Rshigh	13.20	20.82	7.34	4.82	20.80	0.02	1.89	3.54	17.84	0.61	90.88
Boh2	**Initial Conditions**	6.22	7.42	1.12	0.95	4.97	0.00	0.98	1.75	3.74	0.07	27.22
	Baselow	6.07	7.24	1.09	0.93	4.86	0.00	1.16	2.06	3.72	0.07	27.21
	Baselinear	5.93	7.08	1.07	0.91	4.76	0.00	1.32	2.36	3.71	0.07	27.21
	Basehigh	5.77	6.90	1.05	0.89	4.65	0.00	1.50	2.67	3.70	0.07	27.21
	Planlow	6.08	7.25	1.10	0.93	4.87	0.00	1.15	2.04	3.72	0.07	27.21
	Planlinear	5.97	7.12	1.08	0.91	4.79	0.00	1.28	2.27	3.71	0.07	27.21
	Planhigh	5.81	6.95	1.06	0.89	4.69	0.00	1.45	2.58	3.71	0.07	27.21
	RSlow	6.06	7.23	1.09	0.92	4.86	0.00	1.17	2.08	3.72	0.07	27.21
	Rslinear	5.97	7.13	1.08	0.91	4.80	0.00	1.27	2.26	3.72	0.07	27.21
	Rshigh	5.91	7.06	1.08	0.91	4.76	0.00	1.33	2.37	3.71	0.07	27.21

		CBPO Land Use (sq. km)										
		Hi Till	**Lo Till**	**Pasture**	**Hay**	**Non Ag**	**Manure**	**Impervious Urban**	**Pervious Urban**	**Forest**	**Water**	**Total**
Boh3	**Initial Conditions**	1.93	2.20	0.25	0.24	1.34	0.00	0.33	0.59	0.89	0.00	7.77
	Baselow	1.88	2.15	0.24	0.23	1.31	0.00	0.38	0.69	0.88	0.00	7.77
	Baselinear	1.84	2.10	0.24	0.23	1.28	0.00	0.43	0.78	0.88	0.00	7.77
	Basehigh	1.79	2.04	0.23	0.22	1.25	0.00	0.49	0.88	0.87	0.00	7.77
	Planlow	1.88	2.14	0.24	0.23	1.31	0.00	0.39	0.69	0.88	0.00	7.77
	Planlinear	1.83	2.09	0.24	0.23	1.28	0.00	0.44	0.79	0.88	0.00	7.77
	Planhigh	1.77	2.03	0.23	0.22	1.24	0.00	0.50	0.90	0.87	0.00	7.77
	RSlow	1.85	2.11	0.24	0.23	1.29	0.00	0.41	0.75	0.88	0.00	7.77
	Rslinear	1.81	2.07	0.24	0.23	1.27	0.00	0.46	0.82	0.88	0.00	7.77
	Rshigh	1.79	2.05	0.23	0.22	1.25	0.00	0.48	0.86	0.88	0.00	7.77
Boh4	**Initial Conditions**	0.68	0.76	0.08	0.08	0.45	0.00	0.00	0.01	0.31	0.00	2.36
	Baselow	0.67	0.75	0.08	0.08	0.45	0.00	0.01	0.02	0.31	0.00	2.36
	Baselinear	0.67	0.75	0.08	0.08	0.44	0.00	0.01	0.03	0.30	0.00	2.36
	Basehigh	0.66	0.74	0.07	0.08	0.44	0.00	0.02	0.05	0.30	0.00	2.36
	Planlow	0.67	0.76	0.08	0.08	0.45	0.00	0.01	0.02	0.31	0.00	2.36
	Planlinear	0.67	0.75	0.08	0.08	0.44	0.00	0.01	0.03	0.31	0.00	2.36
	Planhigh	0.66	0.75	0.08	0.08	0.44	0.00	0.02	0.04	0.30	0.00	2.36
	RSlow	0.67	0.76	0.08	0.08	0.45	0.00	0.01	0.02	0.31	0.00	2.36
	Rslinear	0.67	0.75	0.08	0.08	0.44	0.00	0.01	0.02	0.30	0.00	2.36
	Rshigh	0.67	0.75	0.08	0.08	0.44	0.00	0.01	0.03	0.30	0.00	2.36

Table 26. Predicted CBPO Land Use Change from 2005 for the Bohemia River Watersheds

		Change in land use compared to CCAP 2005 (sq. km)									
		Hi Till	**Lo Till**	**Pasture**	**Hay**	**Non Ag**	**Manure**	**Impervious Urban**	**Pervious Urban**	**Forest**	**Water**
Boh1	**Initial Conditions**	-	-	-	-	-	-	-	-	-	-
	Baselow	-0.18	-0.24	-0.05	-0.04	-0.18	0.00	0.25	0.47	-0.04	0.00
	Baselinear	-0.33	-0.41	-0.08	-0.06	-0.30	0.00	0.43	0.80	-0.05	0.00
	Basehigh	-0.50	-0.61	-0.10	-0.08	-0.42	0.00	0.63	1.16	-0.07	0.00
	Planlow	-0.17	-0.22	-0.04	-0.03	-0.16	0.00	0.23	0.43	-0.03	0.00
	Planlinear	-0.29	-0.36	-0.06	-0.05	-0.26	0.00	0.37	0.69	-0.04	0.00
	Planhigh	-0.46	-0.56	-0.09	-0.08	-0.39	0.00	0.57	1.05	-0.05	0.00
	RSlow	-0.20	-0.25	-0.05	-0.04	-0.19	0.00	0.26	0.49	-0.02	0.00
	Rslinear	-0.30	-0.37	-0.07	-0.05	-0.26	0.00	0.38	0.70	-0.03	0.00
	Rshigh	-0.36	-0.44	-0.08	-0.06	-0.31	0.00	0.45	0.84	-0.04	0.00
Boh2	**Initial Conditions**	-	-	-	-	-	-	-	-	-	-
	Baselow	-0.15	-0.18	-0.02	-0.02	-0.11	0.00	0.18	0.32	-0.02	0.00
	Baselinear	-0.29	-0.34	-0.04	-0.04	-0.22	0.00	0.34	0.61	-0.03	0.00
	Basehigh	-0.45	-0.52	-0.06	-0.06	-0.32	0.00	0.52	0.93	-0.04	0.00
	Planlow	-0.14	-0.16	-0.02	-0.02	-0.10	0.00	0.16	0.29	-0.01	0.00
	Planlinear	-0.26	-0.29	-0.04	-0.03	-0.18	0.00	0.29	0.53	-0.02	0.00
	Planhigh	-0.41	-0.47	-0.05	-0.05	-0.29	0.00	0.46	0.83	-0.03	0.00
	RSlow	-0.16	-0.19	-0.02	-0.02	-0.11	0.00	0.19	0.33	-0.01	0.00
	Rslinear	-0.25	-0.29	-0.03	-0.03	-0.18	0.00	0.29	0.51	-0.02	0.00
	Rshigh	-0.31	-0.35	-0.04	-0.04	-0.21	0.00	0.35	0.62	-0.02	0.00

		Change in land use compared to CCAP 2005 (sq. km)									
		Hi Till	Lo Till	Pasture	Hay	Non Ag	Manure	Impervious Urban	Pervious Urban	Forest	Water
Boh3	**Initial Conditions**	-	-	-	-	-	-	-	-	-	-
	Baselow	-0.05	-0.05	-0.01	-0.01	-0.03	0.00	0.06	0.10	-0.01	0.00
	Baselinear	-0.09	-0.11	-0.01	-0.01	-0.06	0.00	0.11	0.19	-0.01	0.00
	Basehigh	-0.14	-0.16	-0.02	-0.02	-0.10	0.00	0.16	0.29	-0.02	0.00
	Planlow	-0.05	-0.06	-0.01	-0.01	-0.04	0.00	0.06	0.11	0.00	0.00
	Planlinear	-0.10	-0.11	-0.01	-0.01	-0.07	0.00	0.11	0.20	-0.01	0.00
	Planhigh	-0.16	-0.18	-0.02	-0.02	-0.10	0.00	0.18	0.31	-0.02	0.00
	RSlow	-0.08	-0.09	-0.01	-0.01	-0.05	0.00	0.09	0.16	-0.01	0.00
	Rslinear	-0.12	-0.13	-0.01	-0.01	-0.08	0.00	0.13	0.23	-0.01	0.00
	Rshigh	-0.14	-0.15	-0.02	-0.02	-0.09	0.00	0.15	0.27	-0.01	0.00
Boh4	**Initial Conditions**	-	-	-	-	-	-	-	-	-	-
	Baselow	-0.01	-0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
	Baselinear	-0.01	-0.01	0.00	0.00	-0.01	0.00	0.01	0.02	0.00	0.00
	Basehigh	-0.02	-0.02	0.00	0.00	-0.01	0.00	0.02	0.03	0.00	0.00
	Planlow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Planlinear	-0.01	-0.01	0.00	0.00	-0.01	0.00	0.01	0.02	0.00	0.00
	Planhigh	-0.01	-0.02	0.00	0.00	-0.01	0.00	0.01	0.03	0.00	0.00
	RSlow	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
	Rslinear	-0.01	-0.01	0.00	0.00	-0.01	0.00	0.01	0.01	0.00	0.00
	Rshigh	-0.01	-0.01	0.00	0.00	-0.01	0.00	0.01	0.02	0.00	0.00

Table 27. Tabulated CBPO Land Use for the Trappe Creek Watersheds

		CBPO Land Use (sq. km)										
		Hi Till	**Lo Till**	**Pasture**	**Hay**	**Non Ag**	**Manure**	**Impervious Urban**	**Pervious Urban**	**Forest**	**Water**	**Total**
Trp1	**Initial Conditions**	7.03	0.53	0.63	0.09	2.51	0.01	2.59	3.89	8.23	0.40	25.91
	Baselow	6.78	0.52	0.61	0.09	2.42	0.01	2.90	4.34	7.85	0.40	25.91
	Baselinear	6.61	0.50	0.59	0.08	2.36	0.01	3.10	4.64	7.62	0.40	25.91
	Basehigh	6.48	0.49	0.58	0.08	2.32	0.01	3.25	4.87	7.43	0.40	25.91
	Planlow	6.75	0.51	0.60	0.09	2.41	0.01	2.92	4.38	7.83	0.40	25.91
	Planlinear	6.57	0.50	0.59	0.08	2.35	0.01	3.12	4.68	7.61	0.40	25.91
	Planhigh	6.40	0.49	0.57	0.08	2.29	0.01	3.30	4.93	7.44	0.40	25.91
	RSlow	6.64	0.50	0.59	0.08	2.37	0.01	3.03	4.54	7.74	0.40	25.91
	Rslinear	6.43	0.49	0.57	0.08	2.30	0.01	3.24	4.85	7.54	0.40	25.90
	Rshigh	6.34	0.48	0.57	0.08	2.27	0.01	3.33	4.97	7.46	0.40	25.91
Trp2	**Initial Conditions**	1.97	0.15	0.18	0.02	0.70	0.00	1.03	1.41	1.85	0.06	7.37
	Baselow	1.88	0.14	0.17	0.02	0.67	0.00	1.17	1.61	1.66	0.06	7.38
	Baselinear	1.81	0.14	0.16	0.02	0.65	0.00	1.25	1.73	1.56	0.06	7.38
	Basehigh	1.77	0.13	0.16	0.02	0.63	0.00	1.31	1.82	1.48	0.06	7.38
	Planlow	1.87	0.14	0.17	0.02	0.67	0.00	1.18	1.63	1.63	0.06	7.38
	Planlinear	1.80	0.14	0.16	0.02	0.64	0.00	1.27	1.76	1.51	0.06	7.37
	Planhigh	1.75	0.13	0.16	0.02	0.62	0.00	1.35	1.87	1.42	0.06	7.38
	RSlow	1.85	0.14	0.16	0.02	0.66	0.00	1.23	1.71	1.54	0.06	7.38
	Rslinear	1.78	0.14	0.16	0.02	0.63	0.00	1.33	1.85	1.41	0.06	7.37
	Rshigh	1.75	0.13	0.16	0.02	0.62	0.00	1.37	1.90	1.36	0.06	7.38
Trp3	**Initial Conditions**	0.94	0.07	0.08	0.01	0.33	0.00	0.14	0.22	0.74	0.00	2.54
	Baselow	0.89	0.07	0.08	0.01	0.32	0.00	0.19	0.29	0.69	0.00	2.54
	Baselinear	0.87	0.07	0.08	0.01	0.31	0.00	0.22	0.33	0.65	0.00	2.54

		Change in land use compared to CCAP 2005 (sq. km)										
		Hi Till	Lo Till	Pasture	Hay	Non Ag	Manure	Impervious Urban	Pervious Urban	Forest	Water	Total
Trp3	**Basehigh**	0.85	0.06	0.08	0.01	0.30	0.00	0.24	0.36	0.63	0.00	2.54
	Planlow	0.89	0.07	0.08	0.01	0.32	0.00	0.19	0.29	0.69	0.00	2.54
	Planlinear	0.87	0.07	0.08	0.01	0.31	0.00	0.22	0.33	0.65	0.00	2.54
	Planhigh	0.85	0.06	0.08	0.01	0.30	0.00	0.25	0.37	0.62	0.00	2.54
	RSlow	0.90	0.07	0.08	0.01	0.32	0.00	0.20	0.31	0.66	0.00	2.54
	Rslinear	0.87	0.07	0.08	0.01	0.31	0.00	0.23	0.35	0.62	0.00	2.54
	Rshigh	0.86	0.07	0.08	0.01	0.31	0.00	0.24	0.37	0.61	0.00	2.54

Table 28. Predicted CBPO Land Use Change from 2005 for the Trappe Creek Watersheds

		Change in land use compared to CCAP 2005 (sq. km)									
		Hi Till	Lo Till	Pasture	Hay	Non Ag	Manure	Impervious Urban	Pervious Urban	Forest	Water
Trp1	**Initial Conditions**	-	-	-	-	-	-	-	-	-	-
	Baselow	-0.25	-0.02	-0.02	0.00	-0.09	0.00	0.31	0.45	-0.38	0.00
	Baselinear	-0.42	-0.03	-0.04	-0.01	-0.15	0.00	0.51	0.75	-0.61	0.00
	Basehigh	-0.55	-0.04	-0.05	-0.01	-0.20	0.00	0.66	0.98	-0.80	0.00
	Planlow	-0.27	-0.02	-0.02	0.00	-0.10	0.00	0.33	0.49	-0.40	0.00
	Planlinear	-0.46	-0.03	-0.04	-0.01	-0.16	0.00	0.53	0.79	-0.62	0.00
	Planhigh	-0.63	-0.05	-0.06	-0.01	-0.23	0.00	0.71	1.04	-0.78	0.00
	RSlow	-0.39	-0.03	-0.04	0.00	-0.14	0.00	0.44	0.65	-0.49	0.00

		Change in land use compared to CCAP 2005 (sq. km)									
		Hi Till	Lo Till	Pasture	Hay	Non Ag	Manure	Impervious Urban	Pervious Urban	Forest	Water
Trp 1	**Rslinear**	-0.60	-0.04	-0.05	-0.01	-0.21	0.00	0.65	0.96	-0.69	0.00
	Rshigh	-0.69	-0.05	-0.06	-0.01	-0.24	0.00	0.74	1.08	-0.77	0.00
Trp2	**Initial Conditions**	-	-	-	-	-	-	-	-	-	-
	Baselow	-0.10	-0.01	-0.01	0.00	-0.03	0.00	0.14	0.20	-0.19	0.00
	Baselinear	-0.16	-0.01	-0.01	0.00	-0.06	0.00	0.22	0.32	-0.29	0.00
	Basehigh	-0.21	-0.02	-0.02	0.00	-0.07	0.00	0.28	0.40	-0.37	0.00
	Planlow	-0.10	-0.01	-0.01	0.00	-0.04	0.00	0.16	0.22	-0.22	0.00
	Planlinear	-0.17	-0.01	-0.01	0.00	-0.06	0.00	0.24	0.35	-0.34	0.00
	Planhigh	-0.23	-0.02	-0.02	0.00	-0.08	0.00	0.32	0.46	-0.43	0.00
	RSlow	-0.12	-0.01	-0.01	0.00	-0.05	0.00	0.20	0.29	-0.31	0.00
	Rslinear	-0.19	-0.02	-0.02	0.00	-0.07	0.00	0.30	0.44	-0.44	0.00
	Rshigh	-0.22	-0.02	-0.02	0.00	-0.08	0.00	0.34	0.49	-0.49	0.00
Trp3	**Initial Conditions**	-	-	-	-	-	-	-	-	-	-
	Baselow	-0.04	0.00	0.00	0.00	-0.02	0.00	0.05	0.07	-0.05	0.00
	Baselinear	-0.07	-0.01	-0.01	0.00	-0.02	0.00	0.08	0.11	-0.09	0.00
	Basehigh	-0.08	-0.01	-0.01	0.00	-0.03	0.00	0.10	0.14	-0.11	0.00
	Planlow	-0.04	0.00	0.00	0.00	-0.02	0.00	0.05	0.07	-0.06	0.00
	Planlinear	-0.06	0.00	-0.01	0.00	-0.02	0.00	0.08	0.11	-0.09	0.00
	Planhigh	-0.09	-0.01	-0.01	0.00	-0.03	0.00	0.11	0.15	-0.13	0.00
	RSlow	-0.04	0.00	0.00	0.00	-0.01	0.00	0.06	0.09	-0.09	0.00
	Rslinear	-0.07	-0.01	-0.01	0.00	-0.03	0.00	0.09	0.13	-0.12	0.00
	Rshigh	-0.08	-0.01	-0.01	0.00	-0.03	0.00	0.11	0.15	-0.14	0.00

Table 29.Tabulated CBPO Land Use for the Tred Avon River Watersheds

		CBPO Land Use (sq. km)										
		Hi Till	Lo Till	Pasture	Hay	Non Ag	Manure	Impervious Urban	Pervious Urban	Forest	Water	Total
TrdA1	**Initial Conditions**	12.02	23.94	1.05	0.57	5.12	0.00	7.72	12.36	30.66	1.03	94.47
	Baselow	11.68	23.27	1.02	0.55	4.98	0.00	8.37	13.51	30.07	1.02	94.47
	Baselinear	11.49	22.90	1.00	0.54	4.90	0.00	8.71	14.12	29.79	1.01	94.47
	Basehigh	11.14	22.20	0.97	0.53	4.75	0.00	9.37	15.28	29.22	1.00	94.47
	Planlow	11.71	23.33	1.02	0.55	4.99	0.00	8.31	13.41	30.12	1.02	94.47
	Planlinear	11.56	23.02	1.01	0.55	4.92	0.00	8.59	13.91	29.89	1.02	94.47
	Planhigh	11.24	22.40	0.98	0.53	4.79	0.00	9.16	14.91	29.45	1.01	94.47
	RSlow	11.64	23.20	1.02	0.55	4.96	0.00	8.41	13.58	30.08	1.03	94.47
	Rslinear	11.49	22.90	1.01	0.54	4.90	0.00	8.68	14.07	29.85	1.02	94.47
	Rshigh	11.39	22.70	1.00	0.54	4.85	0.00	8.87	14.41	29.69	1.02	94.47
TrdA2	**Initial Conditions**	2.01	3.99	0.17	0.09	0.85	0.00	5.04	6.94	4.33	0.11	23.54
	Baselow	1.84	3.66	0.16	0.09	0.78	0.00	5.35	7.48	4.08	0.10	23.54
	Baselinear	1.74	3.46	0.15	0.08	0.74	0.00	5.51	7.78	3.97	0.10	23.54
	Basehigh	1.55	3.08	0.14	0.07	0.66	0.00	5.86	8.38	3.70	0.10	23.54
	Planlow	1.81	3.60	0.16	0.09	0.77	0.00	5.40	7.58	4.04	0.11	23.54
	Planlinear	1.71	3.40	0.15	0.08	0.73	0.00	5.57	7.88	3.92	0.11	23.54
	Planhigh	1.51	3.01	0.13	0.07	0.64	0.00	5.92	8.49	3.67	0.10	23.54
	RSlow	1.74	3.46	0.15	0.08	0.74	0.00	5.52	7.79	3.96	0.11	23.54
	Rslinear	1.64	3.26	0.14	0.08	0.70	0.00	5.70	8.10	3.82	0.11	23.54
	Rshigh	1.58	3.14	0.14	0.07	0.67	0.00	5.80	8.29	3.74	0.11	23.54

		CBPO Land Use (sq. km)										
		Hi Till	Lo Till	Pasture	Hay	Non Ag	Manure	Impervious Urban	Pervious Urban	Forest	Water	Total
TrdA3a	**Initial Conditions**	0.75	1.49	0.06	0.04	0.32	0.00	1.95	2.22	0.93	0.00	7.75
	Baselow	0.68	1.36	0.06	0.03	0.29	0.00	2.05	2.40	0.87	0.00	7.75
	Baselinear	0.65	1.29	0.06	0.03	0.28	0.00	2.10	2.50	0.85	0.00	7.75
	Basehigh	0.57	1.14	0.05	0.03	0.24	0.00	2.22	2.71	0.79	0.00	7.75
	Planlow	0.67	1.34	0.06	0.03	0.29	0.00	2.06	2.43	0.87	0.00	7.75
	Planlinear	0.63	1.26	0.06	0.03	0.27	0.00	2.13	2.54	0.83	0.00	7.75
	Planhigh	0.56	1.11	0.05	0.03	0.24	0.00	2.24	2.74	0.79	0.00	7.75
	RSlow	0.64	1.28	0.06	0.03	0.27	0.00	2.11	2.51	0.85	0.00	7.75
	Rslinear	0.60	1.20	0.05	0.03	0.26	0.00	2.17	2.61	0.83	0.00	7.75
	Rshigh	0.58	1.16	0.05	0.03	0.25	0.00	2.20	2.67	0.81	0.00	7.75
TrdA3b	**Initial Conditions**	0.94	1.86	0.08	0.04	0.40	0.00	1.13	1.77	1.60	0.00	7.83
	Baselow	0.86	1.72	0.08	0.04	0.37	0.00	1.24	2.00	1.51	0.00	7.83
	Baselinear	0.83	1.64	0.07	0.04	0.35	0.00	1.30	2.12	1.47	0.00	7.83
	Basehigh	0.75	1.50	0.07	0.04	0.32	0.00	1.42	2.36	1.37	0.00	7.83
	Planlow	0.84	1.67	0.07	0.04	0.36	0.00	1.29	2.09	1.47	0.00	7.83
	Planlinear	0.80	1.59	0.07	0.04	0.34	0.00	1.35	2.22	1.42	0.00	7.83
	Planhigh	0.72	1.44	0.06	0.03	0.31	0.00	1.47	2.48	1.31	0.00	7.83
	RSlow	0.80	1.59	0.07	0.04	0.34	0.00	1.36	2.24	1.39	0.00	7.83
	Rslinear	0.75	1.50	0.07	0.04	0.32	0.00	1.44	2.41	1.31	0.00	7.83
	Rshigh	0.73	1.46	0.06	0.03	0.31	0.00	1.47	2.47	1.28	0.00	7.83

		CBPO Land Use (sq. km)										
		Hi Till	Lo Till	Pasture	Hay	Non Ag	Manure	Impervious Urban	Pervious Urban	Forest	Water	Total
TrdA4a	**Initial Conditions**	0.11	0.23	0.01	0.01	0.05	0.00	1.24	1.24	0.35	0.00	3.23
	Baselow	0.09	0.19	0.01	0.00	0.04	0.00	1.28	1.31	0.32	0.00	3.24
	Baselinear	0.08	0.17	0.01	0.00	0.04	0.00	1.29	1.34	0.30	0.00	3.24
	Basehigh	0.06	0.12	0.01	0.00	0.03	0.00	1.34	1.41	0.27	0.00	3.24
	Planlow	0.09	0.18	0.01	0.00	0.04	0.00	1.29	1.32	0.31	0.00	3.23
	Planlinear	0.08	0.15	0.01	0.00	0.03	0.00	1.31	1.36	0.29	0.00	3.24
	Planhigh	0.05	0.11	0.01	0.00	0.02	0.00	1.35	1.43	0.26	0.00	3.24
	RSlow	0.08	0.16	0.01	0.00	0.03	0.00	1.30	1.35	0.30	0.00	3.24
	Rslinear	0.07	0.13	0.01	0.00	0.03	0.00	1.32	1.39	0.29	0.00	3.24
	Rshigh	0.06	0.12	0.01	0.00	0.03	0.00	1.34	1.41	0.28	0.00	3.24
TrdA4b	**Initial Conditions**	0.60	1.20	0.05	0.03	0.26	0.00	0.13	0.27	0.79	0.00	3.33
	Baselow	0.57	1.13	0.05	0.03	0.24	0.00	0.18	0.37	0.77	0.00	3.33
	Baselinear	0.55	1.09	0.05	0.03	0.23	0.00	0.20	0.42	0.77	0.00	3.33
	Basehigh	0.51	1.01	0.04	0.02	0.22	0.00	0.25	0.51	0.76	0.00	3.33
	Planlow	0.56	1.11	0.05	0.03	0.24	0.00	0.19	0.39	0.77	0.00	3.33
	Planlinear	0.54	1.07	0.05	0.03	0.23	0.00	0.22	0.45	0.76	0.00	3.33
	Planhigh	0.50	0.99	0.04	0.02	0.21	0.00	0.27	0.55	0.75	0.00	3.33
	RSlow	0.54	1.07	0.05	0.03	0.23	0.00	0.21	0.44	0.76	0.00	3.33
	Rslinear	0.52	1.04	0.05	0.02	0.22	0.00	0.24	0.49	0.76	0.00	3.33
	Rshigh	0.51	1.01	0.04	0.02	0.22	0.00	0.25	0.52	0.75	0.00	3.33

Table 30. Predicted CBPO Land Use Change from 2005 for the Tred Avon River Watersheds

		Change in land use compared to CCAP 2005 (sq. km)									
		Hi Till	**Lo Till**	**Pasture**	**Hay**	**Non Ag**	**Manure**	**Impervious Urban**	**Pervious Urban**	**Forest**	**Water**
TrdA1	**Initial Conditions**	-	-	-	-	-	-	-	-	-	-
	Baselow	-0.34	-0.68	-0.03	-0.02	-0.15	0.00	0.65	1.15	-0.58	-0.01
	Baselinear	-0.53	-1.05	-0.05	-0.02	-0.22	0.00	0.99	1.76	-0.87	-0.02
	Basehigh	-0.88	-1.74	-0.08	-0.04	-0.37	0.00	1.65	2.92	-1.44	-0.03
	Planlow	-0.31	-0.62	-0.03	-0.01	-0.13	0.00	0.59	1.05	-0.53	-0.01
	Planlinear	-0.46	-0.92	-0.04	-0.02	-0.20	0.00	0.88	1.55	-0.77	-0.01
	Planhigh	-0.78	-1.55	-0.07	-0.04	-0.33	0.00	1.44	2.54	-1.21	-0.02
	RSlow	-0.38	-0.75	-0.03	-0.02	-0.16	0.00	0.69	1.22	-0.58	0.00
	Rslinear	-0.52	-1.04	-0.05	-0.02	-0.22	0.00	0.97	1.71	-0.81	-0.01
	Rshigh	-0.63	-1.25	-0.05	-0.03	-0.27	0.00	1.16	2.04	-0.97	-0.01
TrdA2	**Initial Conditions**	-	-	-	-	-	-	-	-	-	-
	Baselow	-0.17	-0.34	-0.01	-0.01	-0.07	0.00	0.31	0.55	-0.25	-0.01
	Baselinear	-0.27	-0.53	-0.02	-0.01	-0.11	0.00	0.48	0.84	-0.36	-0.01
	Basehigh	-0.46	-0.91	-0.04	-0.02	-0.19	0.00	0.82	1.45	-0.63	-0.01
	Planlow	-0.20	-0.40	-0.02	-0.01	-0.08	0.00	0.36	0.64	-0.29	0.00
	Planlinear	-0.30	-0.59	-0.03	-0.01	-0.13	0.00	0.53	0.94	-0.42	0.00
	Planhigh	-0.49	-0.99	-0.04	-0.02	-0.21	0.00	0.88	1.55	-0.67	-0.01
	RSlow	-0.27	-0.54	-0.02	-0.01	-0.11	0.00	0.48	0.85	-0.37	0.00
	Rslinear	-0.37	-0.74	-0.03	-0.02	-0.16	0.00	0.66	1.16	-0.51	0.00
	Rshigh	-0.43	-0.85	-0.04	-0.02	-0.18	0.00	0.76	1.35	-0.59	0.00

		Change in land use compared to CCAP 2005 (sq. km)									
		Hi Till	Lo Till	Pasture	Hay	Non Ag	Manure	Impervious Urban	Pervious Urban	Forest	Water
TrdA3a	**Initial Conditions**	-	-	-	-	-	-	-	-	-	-
	Baselow	-0.06	-0.12	0.00	0.00	-0.03	0.00	0.10	0.18	-0.06	0.00
	Baselinear	-0.10	-0.20	-0.01	0.00	-0.04	0.00	0.16	0.28	-0.08	0.00
	Basehigh	-0.18	-0.35	-0.01	-0.01	-0.07	0.00	0.28	0.49	-0.14	0.00
	Planlow	-0.07	-0.15	-0.01	0.00	-0.03	0.00	0.12	0.21	-0.07	0.00
	Planlinear	-0.11	-0.23	-0.01	0.00	-0.05	0.00	0.18	0.32	-0.10	0.00
	Planhigh	-0.19	-0.38	-0.02	-0.01	-0.08	0.00	0.29	0.52	-0.15	0.00
	RSlow	-0.10	-0.20	-0.01	0.00	-0.04	0.00	0.16	0.29	-0.08	0.00
	Rslinear	-0.14	-0.29	-0.01	-0.01	-0.06	0.00	0.22	0.39	-0.10	0.00
	Rshigh	-0.17	-0.33	-0.01	-0.01	-0.07	0.00	0.25	0.45	-0.12	0.00
TrdA3b	**Initial Conditions**	-	-	-	-	-	-	-	-	-	-
	Baselow	-0.07	-0.14	-0.01	0.00	-0.03	0.00	0.11	0.23	-0.09	0.00
	Baselinear	-0.11	-0.22	-0.01	-0.01	-0.05	0.00	0.17	0.35	-0.13	0.00
	Basehigh	-0.18	-0.36	-0.02	-0.01	-0.08	0.00	0.29	0.59	-0.23	0.00
	Planlow	-0.09	-0.19	-0.01	0.00	-0.04	0.00	0.15	0.32	-0.13	0.00
	Planlinear	-0.14	-0.27	-0.01	-0.01	-0.06	0.00	0.22	0.45	-0.18	0.00
	Planhigh	-0.21	-0.42	-0.02	-0.01	-0.09	0.00	0.34	0.71	-0.29	0.00
	RSlow	-0.14	-0.28	-0.01	-0.01	-0.06	0.00	0.23	0.47	-0.21	0.00
	Rslinear	-0.18	-0.37	-0.02	-0.01	-0.08	0.00	0.31	0.64	-0.29	0.00
	Rshigh	-0.20	-0.41	-0.02	-0.01	-0.09	0.00	0.34	0.70	-0.32	0.00

		Change in land use compared to CCAP 2005 (sq. km)									
		Hi Till	**Lo Till**	**Pasture**	**Hay**	**Non Ag**	**Manure**	**Impervious Urban**	**Pervious Urban**	**Forest**	**Water**
TrdA4a	**Initial Conditions**	-	-	-	-	-	-	-	-	-	-
	Baselow	-0.02	-0.04	0.00	0.00	-0.01	0.00	0.04	0.07	-0.03	0.00
	Baselinear	-0.03	-0.06	0.00	0.00	-0.01	0.00	0.06	0.10	-0.05	0.00
	Basehigh	-0.05	-0.10	0.00	0.00	-0.02	0.00	0.10	0.17	-0.08	0.00
	Planlow	-0.03	-0.05	0.00	0.00	-0.01	0.00	0.05	0.08	-0.04	0.00
	Planlinear	-0.04	-0.07	0.00	0.00	-0.02	0.00	0.07	0.12	-0.06	0.00
	Planhigh	-0.06	-0.12	0.00	0.00	-0.02	0.00	0.11	0.19	-0.09	0.00
	RSlow	-0.03	-0.07	0.00	0.00	-0.01	0.00	0.06	0.11	-0.05	0.00
	Rslinear	-0.05	-0.09	0.00	0.00	-0.02	0.00	0.08	0.15	-0.06	0.00
	Rshigh	-0.05	-0.11	0.00	0.00	-0.02	0.00	0.10	0.17	-0.07	0.00
TrdA4b	**Initial Conditions**	-	-	-	-	-	-	-	-	-	-
	Baselow	-0.03	-0.07	0.00	0.00	-0.02	0.00	0.05	0.09	-0.02	0.00
	Baselinear	-0.06	-0.11	0.00	0.00	-0.02	0.00	0.07	0.15	-0.02	0.00
	Basehigh	-0.09	-0.18	-0.01	0.00	-0.04	0.00	0.12	0.24	-0.03	0.00
	Planlow	-0.04	-0.09	0.00	0.00	-0.02	0.00	0.06	0.12	-0.02	0.00
	Planlinear	-0.07	-0.13	-0.01	0.00	-0.03	0.00	0.09	0.17	-0.03	0.00
	Planhigh	-0.10	-0.21	-0.01	-0.01	-0.05	0.00	0.13	0.28	-0.04	0.00
	RSlow	-0.06	-0.12	0.00	0.00	-0.03	0.00	0.08	0.16	-0.02	0.00
	Rslinear	-0.08	-0.16	-0.01	0.00	-0.04	0.00	0.11	0.22	-0.03	0.00
	Rshigh	-0.09	-0.19	-0.01	-0.01	-0.04	0.00	0.12	0.25	-0.04	0.00

Table 31. Tabulated CBPO Land Use for the Wicomico River Watersheds

		CBPO Land Use (sq. km)										
		Hi Till	**Lo Till**	**Pasture**	**Hay**	**Non Ag**	**Manure**	**Imperv. Urban**	**Pervious Urban**	**Forest**	**Water**	**Total**
Wic1	**Initial Conditions**	43.75	13.81	3.28	0.97	31.00	0.05	25.60	33.62	94.41	1.67	248.16
	Baselow	41.49	13.10	3.11	0.92	29.40	0.04	29.63	39.06	89.74	1.67	248.16
	Baselinear	39.79	12.60	2.99	0.88	28.20	0.04	32.34	42.72	86.94	1.66	248.16
	Basehigh	38.75	12.28	2.91	0.86	27.46	0.04	33.93	44.87	85.40	1.66	248.16
	Planlow	41.29	13.03	3.10	0.91	29.26	0.04	29.96	39.50	89.40	1.67	248.16
	Planlinear	39.62	12.54	2.97	0.88	28.08	0.04	32.57	43.02	86.79	1.66	248.16
	Planhigh	38.37	12.15	2.88	0.85	27.19	0.04	34.45	45.56	85.01	1.66	248.16
	RSlow	40.70	12.84	3.05	0.90	28.84	0.04	30.66	40.44	89.01	1.67	248.16
	Rslinear	39.13	12.37	2.94	0.87	27.73	0.04	32.93	43.50	86.99	1.67	248.16
	Rshigh	38.43	12.15	2.88	0.85	27.23	0.04	33.97	44.90	86.03	1.67	248.16
Wic2	**Initial Conditions**	15.68	5.81	1.18	0.36	11.20	0.02	5.87	7.39	33.50	0.42	81.43
	Baselow	15.01	5.56	1.13	0.34	10.72	0.02	7.08	9.01	32.14	0.42	81.43
	Baselinear	14.49	5.41	1.09	0.33	10.36	0.02	7.92	10.14	31.26	0.42	81.43
	Basehigh	14.25	5.31	1.07	0.33	10.18	0.02	8.32	10.68	30.86	0.42	81.43
	Planlow	14.95	5.53	1.12	0.34	10.68	0.02	7.18	9.14	32.04	0.42	81.43
	Planlinear	14.48	5.39	1.09	0.33	10.35	0.02	7.95	10.17	31.23	0.42	81.43
	Planhigh	14.16	5.26	1.06	0.32	10.12	0.02	8.45	10.85	30.75	0.42	81.43
	RSlow	14.79	5.46	1.11	0.34	10.56	0.02	7.40	9.44	31.89	0.42	81.43
	Rslinear	14.38	5.33	1.08	0.33	10.27	0.02	8.05	10.31	31.25	0.42	81.43
	Rshigh	14.21	5.26	1.07	0.33	10.15	0.02	8.33	10.68	30.97	0.42	81.43

		CBPO Land Use (sq. km)										
		Hi Till	**Lo Till**	**Pasture**	**Hay**	**Non Ag**	**Manure**	**Imperv. Urban**	**Pervious Urban**	**Forest**	**Water**	**Total**
Wic3	**Initial Conditions**	1.88	0.54	0.14	0.04	1.33	0.00	2.25	2.22	3.59	0.04	12.03
	Baselow	1.74	0.50	0.13	0.04	1.23	0.00	2.50	2.55	3.31	0.04	12.03
	Baselinear	1.63	0.47	0.12	0.04	1.15	0.00	2.66	2.76	3.15	0.04	12.03
	Basehigh	1.61	0.46	0.12	0.04	1.13	0.00	2.71	2.84	3.08	0.04	12.03
	Planlow	1.71	0.49	0.13	0.04	1.20	0.00	2.55	2.62	3.26	0.04	12.03
	Planlinear	1.61	0.46	0.12	0.03	1.13	0.00	2.70	2.82	3.12	0.04	12.03
	Planhigh	1.56	0.44	0.12	0.03	1.10	0.00	2.78	2.93	3.03	0.04	12.03
	RSlow	1.65	0.47	0.12	0.04	1.16	0.00	2.62	2.71	3.21	0.04	12.03
	Rslinear	1.55	0.44	0.12	0.03	1.10	0.00	2.75	2.89	3.10	0.04	12.03
	Rshigh	1.52	0.43	0.11	0.03	1.07	0.00	2.81	2.97	3.04	0.04	12.03
Wic4	**Initial Conditions**	0.15	0.04	0.01	0.00	0.11	0.00	0.95	1.22	0.05	0.00	2.53
	Baselow	0.12	0.03	0.01	0.00	0.08	0.00	0.98	1.27	0.04	0.00	2.53
	Baselinear	0.09	0.03	0.01	0.00	0.06	0.00	1.01	1.30	0.03	0.00	2.53
	Basehigh	0.08	0.02	0.01	0.00	0.06	0.00	1.02	1.31	0.03	0.00	2.53
	Planlow	0.10	0.03	0.01	0.00	0.07	0.00	1.00	1.29	0.04	0.00	2.53
	Planlinear	0.06	0.02	0.00	0.00	0.04	0.00	1.03	1.34	0.03	0.00	2.53
	Planhigh	0.05	0.02	0.00	0.00	0.04	0.00	1.04	1.35	0.02	0.00	2.53
	RSlow	0.07	0.02	0.01	0.00	0.05	0.00	1.03	1.33	0.03	0.00	2.53
	Rslinear	0.04	0.01	0.00	0.00	0.03	0.00	1.06	1.37	0.02	0.00	2.53
	Rshigh	0.03	0.01	0.00	0.00	0.02	0.00	1.07	1.39	0.02	0.00	2.53

Table 32. Predicted CBPO Land Use Change from 2005 for the Wicomico River Watersheds

		Change in land use compared to CCAP 2005 (sq. km)									
		Hi Till	Lo Till	Pasture	Hay	Non Ag	Manure	Impervious Urban	Pervious Urban	Forest	Water
Wic1	**Initial Conditions**	-	-	-	-	-	-	-	-	-	-
	Baselow	-2.26	-0.71	-0.17	-0.05	-1.60	0.00	4.03	5.43	-4.67	-0.01
	Baselinear	-3.96	-1.20	-0.30	-0.09	-2.80	0.00	6.74	9.09	-7.47	-0.01
	Basehigh	-5.00	-1.53	-0.37	-0.11	-3.54	0.00	8.33	11.25	-9.01	-0.02
	Planlow	-2.46	-0.77	-0.18	-0.05	-1.75	0.00	4.36	5.88	-5.00	-0.01
	Planlinear	-4.14	-1.27	-0.31	-0.09	-2.93	0.00	6.97	9.40	-7.62	-0.01
	Planhigh	-5.38	-1.66	-0.40	-0.12	-3.81	-0.01	8.85	11.94	-9.39	-0.02
	RSlow	-3.05	-0.97	-0.23	-0.07	-2.16	0.00	5.06	6.82	-5.39	-0.01
	Rslinear	-4.62	-1.44	-0.35	-0.10	-3.27	0.00	7.33	9.88	-7.42	-0.01
	Rshigh	-5.32	-1.66	-0.40	-0.12	-3.77	-0.01	8.37	11.28	-8.38	-0.01
Wic2	**Initial Conditions**	-	-	-	-	-	-	-	-	-	-
	Baselow	-0.67	-0.25	-0.05	-0.01	-0.48	0.00	1.21	1.62	-1.36	0.00
	Baselinear	-1.18	-0.41	-0.09	-0.03	-0.84	0.00	2.05	2.75	-2.24	0.00
	Basehigh	-1.43	-0.51	-0.11	-0.03	-1.02	0.00	2.45	3.29	-2.64	0.00
	Planlow	-0.73	-0.28	-0.06	-0.02	-0.52	0.00	1.31	1.76	-1.46	0.00
	Planlinear	-1.20	-0.43	-0.09	-0.03	-0.85	0.00	2.08	2.79	-2.26	0.00
	Planhigh	-1.51	-0.55	-0.11	-0.03	-1.08	0.00	2.58	3.46	-2.75	0.00
	RSlow	-0.89	-0.35	-0.07	-0.02	-0.64	0.00	1.53	2.05	-1.61	0.00
	Rslinear	-1.30	-0.49	-0.10	-0.03	-0.93	0.00	2.18	2.92	-2.25	0.00
	Rshigh	-1.47	-0.56	-0.11	-0.03	-1.05	0.00	2.45	3.29	-2.53	0.00

		Change in land use compared to CCAP 2005 (sq. km)									
		Hi Till	Lo Till	Pasture	Hay	Non Ag	Manure	Impervious Urban	Pervious Urban	Forest	Water
Wic3	**Initial Conditions**	-	-	-	-	-	-	-	-	-	-
	Baselow	-0.14	-0.04	-0.01	0.00	-0.10	0.00	0.24	0.33	-0.28	0.00
	Baselinear	-0.25	-0.07	-0.02	-0.01	-0.17	0.00	0.41	0.54	-0.43	0.00
	Basehigh	-0.27	-0.08	-0.02	-0.01	-0.19	0.00	0.46	0.62	-0.50	0.00
	Planlow	-0.17	-0.05	-0.01	0.00	-0.12	0.00	0.30	0.40	-0.33	0.00
	Planlinear	-0.27	-0.08	-0.02	-0.01	-0.19	0.00	0.44	0.59	-0.47	0.00
	Planhigh	-0.33	-0.09	-0.02	-0.01	-0.23	0.00	0.53	0.71	-0.55	0.00
	RSlow	-0.23	-0.07	-0.02	0.00	-0.16	0.00	0.37	0.49	-0.38	0.00
	Rslinear	-0.33	-0.09	-0.02	-0.01	-0.23	0.00	0.50	0.67	-0.49	0.00
	Rshigh	-0.36	-0.10	-0.03	-0.01	-0.26	0.00	0.56	0.75	-0.55	0.00
Wic4	**Initial Conditions**	-	-	-	-	-	-	-	-	-	-
	Baselow	-0.03	-0.01	0.00	0.00	-0.02	0.00	0.03	0.05	-0.01	0.00
	Baselinear	-0.06	-0.02	0.00	0.00	-0.04	0.00	0.06	0.08	-0.02	0.00
	Basehigh	-0.07	-0.02	0.00	0.00	-0.05	0.00	0.07	0.09	-0.02	0.00
	Planlow	-0.05	-0.01	0.00	0.00	-0.03	0.00	0.05	0.07	-0.02	0.00
	Planlinear	-0.09	-0.02	-0.01	0.00	-0.06	0.00	0.09	0.12	-0.03	0.00
	Planhigh	-0.10	-0.03	-0.01	0.00	-0.07	0.00	0.10	0.13	-0.03	0.00
	RSlow	-0.08	-0.02	-0.01	0.00	-0.06	0.00	0.08	0.11	-0.02	0.00
	Rslinear	-0.11	-0.03	-0.01	0.00	-0.08	0.00	0.11	0.15	-0.03	0.00
	Rshigh	-0.12	-0.03	-0.01	0.00	-0.09	0.00	0.12	0.17	-0.04	0.00

Appendix E. Annual Nutrient Loads and Change Relative to the Initial Conditions

Table 33. Predicted Nutrient Loads for the Bohemia River Watersheds

		Average Annual Load [kg/yr]			% Change (2005)		
		Nitrogen	**Phosphorus**	**Sediment**	**Nitrogen**	**Phosphorus**	**Sediment**
Boh1	**Initial Conditions**	124,317	11,427	5,337,245	-	-	-
	Baselow	123,977	11,449	5,290,549	-0.3%	0.2%	-0.9%
	Baselinear	123,710	11,465	5,253,675	-0.5%	0.3%	-1.6%
	Basehigh	123,411	11,481	5,211,699	-0.7%	0.5%	-2.4%
	Planlow	123,997	11,447	5,293,309	-0.3%	0.2%	-0.8%
	Planlinear	123,780	11,459	5,262,836	-0.4%	0.3%	-1.4%
	Planhigh	123,470	11,475	5,221,134	-0.7%	0.4%	-2.2%
	RSlow	123,942	11,449	5,286,196	-0.3%	0.2%	-1.0%
	Rslinear	123,764	11,458	5,261,304	-0.4%	0.3%	-1.4%
	Rshigh	123,646	11,464	5,245,475	-0.5%	0.3%	-1.7%
Boh2	**Initial Conditions**	41,186	3,511	2,103,401	-	-	-
	Baselow	40,919	3,526	2,066,059	-0.6%	0.4%	-1.8%
	Baselinear	40,665	3,539	2,031,135	-1.3%	0.8%	-3.4%
	Basehigh	40,391	3,554	1,992,028	-1.9%	1.2%	-5.3%
	Planlow	40,932	3,524	2,067,790	-0.6%	0.4%	-1.7%
	Planlinear	40,733	3,536	2,039,392	-1.1%	0.7%	-3.0%
	Planhigh	40,457	3,549	2,001,475	-1.8%	1.1%	-4.8%
	RSlow	40,897	3,526	2,062,158	-0.7%	0.5%	-2.0%
	Rslinear	40,736	3,535	2,039,430	-1.1%	0.7%	-3.0%
	Rshigh	40,637	3,540	2,025,513	-1.3%	0.8%	-3.7%
Boh3	**Initial Conditions**	12,131	1,018	652,308	-	-	-
	Baselow	12,049	1,024	639,614	-0.7%	0.5%	-1.9%
	Baselinear	11,973	1,028	627,926	-1.3%	1.0%	-3.7%
	Basehigh	11,889	1,034	614,881	-2.0%	1.5%	-5.7%
	Planlow	12,039	1,024	638,350	-0.8%	0.5%	-2.1%
	Planlinear	11,955	1,029	625,691	-1.4%	1.0%	-4.1%
	Planhigh	11,861	1,035	611,358	-2.2%	1.6%	-6.3%
	RSlow	11,995	1,026	631,665	-1.1%	0.8%	-3.2%
	Rslinear	11,930	1,030	621,929	-1.7%	1.2%	-4.7%
	Rshigh	11,898	1,032	617,083	-1.9%	1.4%	-5.4%

		Average Annual Load [kg/yr]			% Change (2005)		
		Nitrogen	Phosphorus	Sediment	Nitrogen	Phosphorus	Sediment
Boh4	**Initial Conditions**	3,803	297	218,715	-	-	-
	Baselow	3,792	297	217,335	-0.3%	0.1%	-0.6%
	Baselinear	3,783	297	216,038	-0.5%	0.2%	-1.2%
	Basehigh	3,767	298	213,816	-0.9%	0.5%	-2.2%
	Planlow	3,795	297	217,867	-0.2%	0.0%	-0.4%
	Planlinear	3,786	297	216,423	-0.5%	0.2%	-1.0%
	Planhigh	3,777	298	215,153	-0.7%	0.3%	-1.6%
	RSlow	3,792	297	217,465	-0.3%	0.0%	-0.6%
	Rslinear	3,789	297	216,871	-0.4%	0.1%	-0.8%
	Rshigh	3,783	297	216,112	-0.5%	0.2%	-1.2%

Table 34. Predicted Nutrient Loads for the Trappe Creek Watersheds

		Average Annual Load [kg/yr]			% Change (2005)		
		Nitrogen	Phosphorus	Sediment	Nitrogen	Phosphorus	Sediment
Trp1	**Initial Conditions**	36,053	4,842	836,392	-	-	-
	Baselow	35,791	4,808	816,460	-0.7%	-0.7%	-2.4%
	Baselinear	35,570	4,778	802,251	-1.3%	-1.3%	-4.1%
	Basehigh	35,430	4,759	791,921	-1.7%	-1.7%	-5.3%
	Planlow	35,739	4,800	814,137	-0.9%	-0.9%	-2.7%
	Planlinear	35,484	4,765	798,873	-1.6%	-1.6%	-4.5%
	Planhigh	35,213	4,728	784,420	-2.3%	-2.4%	-6.2%
	RSlow	35,531	4,771	804,025	-1.4%	-1.5%	-3.9%
	Rslinear	35,212	4,727	786,813	-2.3%	-2.4%	-5.9%
	Rshigh	35,064	4,706	779,303	-2.7%	-2.8%	-6.8%
Trp2	**Initial Conditions**	10,621	1,433	237,643	-	-	-
	Baselow	10,553	1,425	230,053	-0.6%	-0.6%	-3.2%
	Baselinear	10,480	1,415	224,556	-1.3%	-1.3%	-5.5%
	Basehigh	10,447	1,411	221,162	-1.6%	-1.6%	-6.9%
	Planlow	10,558	1,426	229,394	-0.6%	-0.5%	-3.5%
	Planlinear	10,506	1,419	224,291	-1.1%	-1.0%	-5.6%
	Planhigh	10,450	1,411	219,737	-1.6%	-1.5%	-7.5%
	RSlow	10,589	1,431	228,115	-0.3%	-0.2%	-4.0%

		Average Annual Load [kg/yr]			% Change (2005)		
		Nitrogen	Phosphorus	Sediment	Nitrogen	Phosphorus	Sediment
Trp 2	**Rslinear**	10,533	1,424	222,494	-0.8%	-0.7%	-6.4%
	Rshigh	10,511	1,421	220,258	-1.0%	-0.9%	-7.3%
Trp3	**Initial Conditions**	4,179	572	104,540	-	-	-
	Baselow	4,129	565	101,214	-1.2%	-1.2%	-3.2%
	Baselinear	4,096	560	99,003	-2.0%	-2.0%	-5.3%
	Basehigh	4,077	557	97,618	-2.5%	-2.5%	-6.6%
	Planlow	4,134	565	101,276	-1.1%	-1.1%	-3.1%
	Planlinear	4,112	563	99,553	-1.6%	-1.6%	-4.8%
	Planhigh	4,086	559	97,617	-2.2%	-2.2%	-6.6%
	RSlow	4,163	570	101,505	-0.4%	-0.3%	-2.9%
	Rslinear	4,122	564	99,096	-1.4%	-1.3%	-5.2%
	Rshigh	4,117	564	98,451	-1.5%	-1.4%	-5.8%

Table 35. Predicted Nutrient Loads for the Tred Avon River Watersheds

		Average Annual Load [kg/yr]			% Change (2005)		
		Nitrogen	Phosphorus	Sediment	Nitrogen	Phosphorus	Sediment
TrdA1	**Initial Conditions**	124,119	11,302	3,723,538	-	-	-
	Baselow	123,558	11,395	3,649,723	-0.5%	0.8%	-2.0%
	Baselinear	123,219	11,440	3,609,335	-0.7%	1.2%	-3.1%
	Basehigh	122,612	11,530	3,532,722	-1.2%	2.0%	-5.1%
	Planlow	123,606	11,387	3,655,934	-0.4%	0.7%	-1.8%
	Planlinear	123,328	11,424	3,622,581	-0.6%	1.1%	-2.7%
	Planhigh	122,716	11,493	3,553,476	-1.1%	1.7%	-4.6%
	RSlow	123,438	11,393	3,641,376	-0.5%	0.8%	-2.2%
	Rslinear	123,168	11,430	3,608,568	-0.8%	1.1%	-3.1%
	Rshigh	122,985	11,455	3,586,262	-0.9%	1.4%	-3.7%
TrdA2	**Initial Conditions**	30,872	3,291	715,606	-	-	-
	Baselow	30,550	3,331	678,322	-1.0%	1.2%	-5.2%
	Baselinear	30,332	3,347	656,812	-1.7%	1.7%	-8.2%
	Basehigh	29,961	3,390	614,703	-2.9%	3.0%	-14.1%

		Average Annual Load [kg/yr]			% Change (2005)		
		Nitrogen	**Phosphorus**	**Sediment**	**Nitrogen**	**Phosphorus**	**Sediment**
TrdA2	**Planlow**	30,494	3,337	671,821	-1.2%	1.4%	-6.1%
	Planlinear	30,289	3,356	650,240	-1.9%	2.0%	-9.1%
	Planhigh	29,872	3,395	606,407	-3.2%	3.1%	-15.3%
	RSlow	30,338	3,349	656,012	-1.7%	1.8%	-8.3%
	Rslinear	30,136	3,370	634,044	-2.4%	2.4%	-11.4%
	Rshigh	30,031	3,384	621,554	-2.7%	2.8%	-13.1%
TrdA3a	**Initial Conditions**	10,922	1,142	256,483	-	-	-
	Baselow	10,770	1,151	242,369	-1.4%	0.8%	-5.5%
	Baselinear	10,671	1,154	233,966	-2.3%	1.1%	-8.8%
	Basehigh	10,472	1,163	216,484	-4.1%	1.9%	-15.6%
	Planlow	10,742	1,152	240,003	-1.6%	0.9%	-6.4%
	Planlinear	10,641	1,157	230,788	-2.6%	1.4%	-10.0%
	Planhigh	10,433	1,164	213,565	-4.5%	1.9%	-16.7%
	RSlow	10,661	1,154	233,325	-2.4%	1.1%	-9.0%
	Rslinear	10,542	1,157	223,858	-3.5%	1.3%	-12.7%
	Rshigh	10,485	1,160	218,857	-4.0%	1.6%	-14.7%
TrdA3b	**Initial Conditions**	11,078	1,105	304,343	-	-	-
	Baselow	10,932	1,121	289,153	-1.3%	1.4%	-5.0%
	Baselinear	10,836	1,127	280,746	-2.2%	2.0%	-7.8%
	Basehigh	10,700	1,145	265,614	-3.4%	3.6%	-12.7%
	Planlow	10,892	1,128	284,073	-1.7%	2.1%	-6.7%
	Planlinear	10,804	1,136	275,332	-2.5%	2.8%	-9.5%
	Planhigh	10,660	1,155	259,277	-3.8%	4.5%	-14.8%
	RSlow	10,830	1,142	275,134	-2.2%	3.3%	-9.6%
	Rslinear	10,755	1,156	265,393	-2.9%	4.6%	-12.8%
	Rshigh	10,717	1,160	261,283	-3.3%	5.0%	-14.1%

		Average Annual Load [kg/yr]			% Change (2005)		
		Nitrogen	**Phosphorus**	**Sediment**	**Nitrogen**	**Phosphorus**	**Sediment**
TrdA4a	**Initial Conditions**	3,903	456	58,266	-	-	-
	Baselow	3,870	462	53,703	-0.9%	1.2%	-7.8%
	Baselinear	3,850	464	51,630	-1.4%	1.6%	-11.4%
	Basehigh	3,815	470	46,791	-2.3%	3.0%	-19.7%
	Planlow	3,861	463	52,783	-1.1%	1.4%	-9.4%
	Planlinear	3,844	466	50,157	-1.5%	2.2%	-13.9%
	Planhigh	3,796	471	45,198	-2.8%	3.1%	-22.4%
	RSlow	3,839	464	50,594	-1.6%	1.8%	-13.2%
	Rslinear	3,811	467	47,796	-2.4%	2.3%	-18.0%
	Rshigh	3,800	468	46,377	-2.7%	2.6%	-20.4%
TrdA4b	**Initial Conditions**	5,296	462	176,158	-	-	-
	Baselow	5,194	465	168,449	-1.9%	0.6%	-4.4%
	Baselinear	5,127	465	163,739	-3.2%	0.7%	-7.1%
	Basehigh	5,012	466	155,631	-5.4%	0.9%	-11.7%
	Planlow	5,164	465	166,265	-2.5%	0.6%	-5.6%
	Planlinear	5,102	466	161,618	-3.7%	0.9%	-8.3%
	Planhigh	4,980	468	152,839	-6.0%	1.3%	-13.2%
	RSlow	5,108	466	162,268	-3.5%	0.8%	-7.9%
	Rslinear	5,051	467	157,929	-4.6%	1.1%	-10.3%
	Rshigh	5,013	468	155,106	-5.3%	1.3%	-12.0%

Table 36. Predicted Nutrient Loads for the Wicomico River Watersheds

		Average Annual Load [kg/yr]			% Change (2005)		
		Nitrogen	**Phosphorus**	**Sediment**	**Nitrogen**	**Phosphorus**	**Sediment**
Wic1	**Initial Conditions**	298,499	40,668	6,516,134	-	-	-
	Baselow	298,217	40,718	6,281,972	-0.1%	0.1%	-3.6%
	Baselinear	297,281	40,633	6,103,637	-0.4%	-0.1%	-6.3%
	Basehigh	296,499	40,552	5,993,614	-0.7%	-0.3%	-8.0%
	Planlow	298,095	40,707	6,259,903	-0.1%	0.1%	-3.9%
	Planlinear	297,034	40,602	6,084,146	-0.5%	-0.2%	-6.6%
	Planhigh	296,019	40,492	5,951,848	-0.8%	-0.4%	-8.7%

		Average Annual Load [kg/yr]			% Change (2005)		
		Nitrogen	**Phosphorus**	**Sediment**	**Nitrogen**	**Phosphorus**	**Sediment**
Wic 1	**RSlow**	297,141	40,581	6,196,280	-0.5%	-0.2%	-4.9%
	Rslinear	295,665	40,407	6,029,095	-0.9%	-0.6%	-7.5%
	Rshigh	295,068	40,341	5,954,955	-1.1%	-0.8%	-8.6%
Wic2	**Initial Conditions**	99,976	13,382	2,291,391	-	-	-
	Baselow	99,803	13,391	2,220,720	-0.2%	0.1%	-3.1%
	Baselinear	99,561	13,373	2,166,953	-0.4%	-0.1%	-5.4%
	Basehigh	99,373	13,358	2,140,502	-0.6%	-0.2%	-6.6%
	Planlow	99,760	13,388	2,214,109	-0.2%	0.0%	-3.4%
	Planlinear	99,541	13,372	2,165,072	-0.4%	-0.1%	-5.5%
	Planhigh	99,285	13,350	2,131,311	-0.7%	-0.2%	-7.0%
	RSlow	99,530	13,362	2,196,657	-0.4%	-0.1%	-4.1%
	Rslinear	99,253	13,337	2,153,220	-0.7%	-0.3%	-6.0%
	Rshigh	99,141	13,328	2,135,422	-0.8%	-0.4%	-6.8%
Wic3	**Initial Conditions**	14,782	2,016	287,896	-	-	-
	Baselow	14,752	2,017	273,127	-0.2%	0.0%	-5.1%
	Baselinear	14,683	2,009	262,089	-0.7%	-0.3%	-9.0%
	Basehigh	14,693	2,012	259,191	-0.6%	-0.2%	-10.0%
	Planlow	14,739	2,016	269,716	-0.3%	0.0%	-6.3%
	Planlinear	14,659	2,006	259,263	-0.8%	-0.5%	-9.9%
	Planhigh	14,629	2,004	253,686	-1.0%	-0.6%	-11.9%
	RSlow	14,653	2,004	263,497	-0.9%	-0.6%	-8.5%
	Rslinear	14,556	1,992	253,355	-1.5%	-1.2%	-12.0%
	Rshigh	14,543	1,991	249,600	-1.6%	-1.3%	-13.3%
Wic4	**Initial Conditions**	3,310	471	36,333	-	-	-
	Baselow	3,248	463	32,725	-1.9%	-1.9%	-9.9%
	Baselinear	3,189	454	29,561	-3.7%	-3.6%	-18.6%
	Basehigh	3,176	453	28,865	-4.1%	-4.0%	-20.6%
	Planlow	3,216	458	31,002	-2.9%	-2.8%	-14.7%
	Planlinear	3,140	447	26,896	-5.2%	-5.1%	-26.0%
	Planhigh	3,122	445	25,907	-5.7%	-5.6%	-28.7%
	RSlow	3,148	448	27,285	-4.9%	-4.9%	-24.9%
	Rslinear	3,095	441	24,438	-6.5%	-6.5%	-32.7%
	Rshigh	3,069	437	22,954	-7.3%	-7.2%	-36.8%

Appendix F. Watershed Peak Discharges

Table 37. Predicted Peak Flows for the Bohemia River Watersheds

		Peak Discharge [m^3/s]					
		2-yr, 24-hr	**5-yr, 24-hr**	**10-yr, 24-hr**	**25-yr, 24-hr**	**50-yr, 24-hr**	**100-yr, 24-hr**
Boh1	**Initial Conditions**	38.6	63.4	86.4	122.5	154.9	191.3
	Baselow	38.8	63.8	86.9	123.1	155.6	192.1
	Baselinear	38.9	63.9	87.0	123.2	155.7	192.3
	Basehigh	38.9	63.9	87.0	123.3	155.8	192.4
	Planlow	38.8	63.8	86.9	123.1	155.6	192.1
	Planlinear	38.8	63.8	86.9	123.1	155.7	192.2
	Planhigh	38.9	63.9	87.0	123.2	155.7	192.3
	RSlow	38.8	63.8	86.9	123.1	155.6	192.1
	Rslinear	38.8	63.8	86.9	123.1	155.7	192.2
	Rshigh	38.8	63.8	86.9	123.2	155.7	192.2
Boh2	**Initial Conditions**	15.7	26.3	36.1	51.0	64.1	78.8
	Baselow	16.0	26.6	36.5	51.5	64.7	79.4
	Baselinear	16.0	26.7	36.6	51.6	64.8	79.6
	Basehigh	16.1	26.8	36.7	51.8	65.0	79.8
	Planlow	16.0	26.6	36.5	51.5	64.7	79.4
	Planlinear	16.0	26.7	36.5	51.6	64.8	79.5
	Planhigh	16.1	26.8	36.6	51.7	64.9	79.7
	RSlow	16.0	26.6	36.5	51.5	64.7	79.4
	Rslinear	16.0	26.7	36.5	51.6	64.8	79.5
	Rshigh	16.0	26.7	36.6	51.6	64.8	79.6
Boh3	**Initial Conditions**	4.4	7.6	10.5	15.0	19.0	23.4
	Baselow	4.6	7.8	10.7	15.3	19.4	23.8
	Baselinear	4.6	7.8	10.8	15.3	19.4	23.9
	Basehigh	4.6	7.8	10.8	15.4	19.5	24.0
	Planlow	4.6	7.8	10.7	15.3	19.4	23.8
	Planlinear	4.6	7.8	10.8	15.3	19.4	23.9
	Planhigh	4.6	7.8	10.8	15.4	19.5	24.0
	RSlow	4.6	7.8	10.7	15.3	19.4	23.8
	Rslinear	4.6	7.8	10.8	15.4	19.4	23.9
	Rshigh	4.6	7.8	10.8	15.4	19.5	23.9

		Peak Discharge [m^3/s]					
		2-yr, 24-hr	5-yr, 24-hr	10-yr, 24-hr	25-yr, 24-hr	50-yr, 24-hr	100-yr, 24-hr
Boh4	Initial Conditions	1.5	2.5	3.4	4.8	6.1	7.5
	Baselow	1.5	2.5	3.4	4.8	6.1	7.5
	Baselinear	1.5	2.5	3.4	4.9	6.1	7.5
	Basehigh	1.5	2.5	3.4	4.9	6.2	7.6
	Planlow	1.5	2.5	3.4	4.8	6.1	7.5
	Planlinear	1.5	2.5	3.4	4.9	6.1	7.5
	Planhigh	1.5	2.5	3.4	4.9	6.1	7.5
	RSlow	1.5	2.5	3.4	4.8	6.1	7.5
	Rslinear	1.5	2.5	3.4	4.8	6.1	7.5
	Rshigh	1.5	2.5	3.4	4.9	6.1	7.5

Table 38. Predicted Peak Flow Changes from 2005 for the Bohemia River Watersheds

		% Change from 2005 Peak Discharge					
		2-yr, 24-hr	5-yr, 24-hr	10-yr, 24-hr	25-yr, 24-hr	50-yr, 24-hr	100-yr, 24-hr
Boh1	Initial Conditions	-	-	-	-	-	-
	Baselow	0.6%	0.6%	0.5%	0.5%	0.4%	0.4%
	Baselinear	0.7%	0.7%	0.6%	0.5%	0.5%	0.5%
	Basehigh	0.9%	0.8%	0.7%	0.6%	0.6%	0.6%
	Planlow	0.6%	0.6%	0.5%	0.5%	0.4%	0.4%
	Planlinear	0.7%	0.6%	0.6%	0.5%	0.5%	0.5%
	Planhigh	0.8%	0.7%	0.6%	0.6%	0.5%	0.5%
	RSlow	0.6%	0.5%	0.5%	0.5%	0.4%	0.4%
	Rslinear	0.7%	0.6%	0.6%	0.5%	0.5%	0.5%
	Rshigh	0.7%	0.6%	0.6%	0.5%	0.5%	0.5%
Boh2	Initial Conditions	-	-	-	-	-	-
	Baselow	1.5%	1.3%	1.1%	1.0%	0.9%	0.8%
	Baselinear	1.8%	1.5%	1.4%	1.2%	1.1%	1.0%
	Basehigh	2.3%	1.9%	1.7%	1.5%	1.4%	1.2%
	Planlow	1.5%	1.3%	1.1%	1.0%	0.9%	0.8%
	Planlinear	1.7%	1.5%	1.3%	1.1%	1.0%	0.9%
	Planhigh	2.0%	1.7%	1.6%	1.3%	1.2%	1.1%
	RSlow	1.5%	1.3%	1.1%	1.0%	0.9%	0.8%

		% Change from 2005 Peak Discharge					
		2-yr, 24-hr	5-yr, 24-hr	10-yr, 24-hr	25-yr, 24-hr	50-yr, 24-hr	100-yr, 24-hr
Boh 2	**Rslinear**	1.8%	1.5%	1.3%	1.2%	1.1%	1.0%
	Rshigh	1.8%	1.6%	1.4%	1.2%	1.1%	1.0%
Boh3	**Initial Conditions**	-	-	-	-	-	-
	Baselow	3.1%	2.6%	2.4%	2.1%	1.9%	1.7%
	Baselinear	3.7%	3.1%	2.8%	2.4%	2.2%	2.0%
	Basehigh	4.5%	3.8%	3.4%	3.0%	2.7%	2.4%
	Planlow	3.2%	2.7%	2.4%	2.1%	1.9%	1.7%
	Planlinear	3.7%	3.2%	2.9%	2.5%	2.3%	2.0%
	Planhigh	4.3%	3.7%	3.3%	2.8%	2.6%	2.3%
	RSlow	3.4%	2.8%	2.6%	2.2%	2.0%	1.8%
	Rslinear	3.8%	3.2%	2.9%	2.5%	2.3%	2.1%
	Rshigh	4.0%	3.4%	3.1%	2.7%	2.4%	2.2%
Boh4	**Initial Conditions**	-	-	-	-	-	-
	Baselow	0.2%	0.3%	0.2%	0.2%	0.2%	0.2%
	Baselinear	0.4%	0.4%	0.4%	0.3%	0.3%	0.3%
	Basehigh	1.2%	1.1%	1.0%	0.8%	0.8%	0.7%
	Planlow	0.2%	0.3%	0.2%	0.1%	0.2%	0.1%
	Planlinear	0.3%	0.3%	0.3%	0.2%	0.2%	0.2%
	Planhigh	0.7%	0.7%	0.6%	0.5%	0.5%	0.4%
	RSlow	0.2%	0.2%	0.2%	0.1%	0.2%	0.1%
	Rslinear	0.2%	0.3%	0.2%	0.2%	0.2%	0.2%
	Rshigh	0.3%	0.4%	0.3%	0.3%	0.3%	0.2%

Table 39. Predicted Peak Flows for the Trappe Creek Watersheds

		Peak Discharge [m^3/s]					
		2-yr, 24-hr	5-yr, 24-hr	10-yr, 24-hr	25-yr, 24-hr	50-yr, 24-hr	100-yr, 24-hr
Trp1	**Initial Conditions**	16.4	24.8	32.5	44.1	54.4	65.8
	Baselow	16.6	25.1	32.8	44.5	54.8	66.2
	Baselinear	16.6	25.1	32.8	44.6	54.9	66.3
	Basehigh	16.6	25.1	32.8	44.6	54.9	66.4
	Planlow	16.6	25.1	32.8	44.5	54.8	66.3
	Planlinear	16.6	25.2	32.9	44.6	54.9	66.4
	Planhigh	16.7	25.2	32.9	44.6	54.9	66.4

		Peak Discharge [m^3/s]					
		2-yr, 24-hr	**5-yr, 24-hr**	**10-yr, 24-hr**	**25-yr, 24-hr**	**50-yr, 24-hr**	**100-yr, 24-hr**
Trp 1	**RSlow**	16.6	25.1	32.9	44.6	54.9	66.4
	Rslinear	16.7	25.2	32.9	44.7	54.9	66.4
	Rshigh	16.7	25.2	32.9	44.7	55.0	66.5
Trp2	**Initial Conditions**	7.2	11.0	14.4	19.4	23.8	28.7
	Baselow	7.3	11.1	14.6	19.6	24.1	28.9
	Baselinear	7.4	11.2	14.6	19.7	24.1	29.0
	Basehigh	7.4	11.2	14.6	19.7	24.2	29.0
	Planlow	7.3	11.2	14.6	19.7	24.1	29.0
	Planlinear	7.4	11.2	14.6	19.7	24.2	29.1
	Planhigh	7.4	11.2	14.6	19.7	24.2	29.1
	RSlow	7.4	11.2	14.6	19.7	24.2	29.1
	Rslinear	7.4	11.2	14.7	19.8	24.2	29.1
	Rshigh	7.4	11.3	14.7	19.8	24.2	29.1
Trp3	**Initial Conditions**	3.3	5.0	6.5	8.7	10.6	12.7
	Baselow	3.4	5.0	6.6	8.8	10.7	12.8
	Baselinear	3.4	5.1	6.6	8.8	10.7	12.8
	Basehigh	3.4	5.1	6.6	8.8	10.7	12.8
	Planlow	3.4	5.0	6.6	8.8	10.7	12.8
	Planlinear	3.4	5.0	6.6	8.8	10.7	12.8
	Planhigh	3.4	5.1	6.6	8.8	10.8	12.8
	RSlow	3.4	5.0	6.6	8.8	10.7	12.8
	Rslinear	3.4	5.1	6.6	8.8	10.8	12.8
	Rshigh	3.4	5.0	6.6	8.8	10.7	12.8

Table 40. Predicted Peak Flow Changes from 2005 for the Trappe Creek Watersheds

		% Change from 2005 Peak Discharge					
		2-yr, 24-hr	5-yr, 24-hr	10-yr, 24-hr	25-yr, 24-hr	50-yr, 24-hr	100-yr, 24-hr
Trp1	**Initial Conditions**	-	-	-	-	-	-
	Baselow	1.1%	1.0%	0.9%	0.8%	0.7%	0.7%
	Baselinear	1.4%	1.2%	1.1%	1.0%	0.9%	0.8%
	Basehigh	1.5%	1.3%	1.1%	1.0%	0.9%	0.9%
	Planlow	1.3%	1.1%	1.0%	0.9%	0.8%	0.8%
	Planlinear	1.5%	1.3%	1.2%	1.1%	1.0%	0.9%
	Planhigh	1.6%	1.4%	1.3%	1.1%	1.0%	0.9%
	RSlow	1.5%	1.3%	1.2%	1.0%	0.9%	0.9%
	Rslinear	1.7%	1.4%	1.3%	1.1%	1.1%	1.0%
	Rshigh	1.7%	1.5%	1.3%	1.2%	1.1%	1.0%
Trp2	**Initial Conditions**	-	-	-	-	-	-
	Baselow	1.8%	1.5%	1.4%	1.2%	1.1%	1.0%
	Baselinear	2.2%	1.8%	1.6%	1.4%	1.3%	1.2%
	Basehigh	2.4%	2.0%	1.8%	1.6%	1.5%	1.4%
	Planlow	2.0%	1.7%	1.5%	1.3%	1.2%	1.1%
	Planlinear	2.5%	2.1%	1.9%	1.7%	1.5%	1.4%
	Planhigh	2.6%	2.2%	2.0%	1.8%	1.6%	1.5%
	RSlow	2.5%	2.1%	1.9%	1.7%	1.5%	1.4%
	Rslinear	2.9%	2.4%	2.2%	2.0%	1.8%	1.6%
	Rshigh	3.0%	2.5%	2.3%	2.0%	1.8%	1.7%
Trp3	**Initial Conditions**	-	-	-	-	-	-
	Baselow	1.6%	1.3%	1.2%	1.0%	0.9%	0.9%
	Baselinear	1.9%	1.6%	1.4%	1.2%	1.1%	1.0%
	Basehigh	1.9%	1.6%	1.4%	1.2%	1.1%	1.0%
	Planlow	1.7%	1.4%	1.2%	1.1%	1.0%	0.9%
	Planlinear	1.7%	1.4%	1.3%	1.1%	1.0%	0.9%
	Planhigh	2.1%	1.7%	1.5%	1.3%	1.2%	1.1%
	RSlow	1.6%	1.4%	1.2%	1.1%	1.0%	0.9%
	Rslinear	2.0%	1.7%	1.5%	1.3%	1.2%	1.1%
	Rshigh	1.7%	1.4%	1.2%	1.1%	1.0%	0.9%

Table 41. Predicted Peak Flows for the Tred Avon River Watersheds

		Peak Discharge [m^3/s]					
		2-yr, 24-hr	**5-yr, 24-hr**	**10-yr, 24-hr**	**25-yr, 24-hr**	**50-yr, 24-hr**	**100-yr, 24-hr**
TrdA1	**Initial Conditions**	50.6	75.3	97.3	131.2	161.7	195.8
	Baselow	51.1	76.0	98.1	132.1	162.8	197.0
	Baselinear	51.2	76.1	98.2	132.3	162.9	197.2
	Basehigh	51.3	76.3	98.4	132.6	163.3	197.5
	Planlow	51.1	76.0	98.1	132.1	162.8	197.0
	Planlinear	51.2	76.1	98.2	132.3	163.0	197.2
	Planhigh	51.3	76.3	98.4	132.6	163.2	197.5
	RSlow	51.1	76.0	98.1	132.2	162.9	197.1
	Rslinear	51.2	76.1	98.3	132.4	163.0	197.3
	Rshigh	51.3	76.2	98.3	132.5	163.1	197.4
TrdA2	**Initial Conditions**	12.5	19.5	25.7	35.4	44.2	54.0
	Baselow	12.9	19.9	26.3	36.1	44.9	54.8
	Baselinear	12.9	20.0	26.4	36.2	45.0	55.0
	Basehigh	13.0	20.1	26.6	36.4	45.3	55.2
	Planlow	12.9	20.0	26.3	36.1	45.0	54.9
	Planlinear	13.0	20.0	26.4	36.3	45.1	55.1
	Planhigh	13.1	20.2	26.6	36.5	45.4	55.3
	RSlow	12.9	20.0	26.4	36.2	45.1	55.0
	Rslinear	13.0	20.1	26.5	36.3	45.2	55.2
	Rshigh	13.0	20.2	26.6	36.4	45.3	55.3
TrdA3a	**Initial Conditions**	6.5	9.8	12.8	17.2	21.1	25.4
	Baselow	6.4	9.7	12.7	17.1	20.9	25.2
	Baselinear	6.4	9.7	12.7	17.1	20.9	25.2
	Basehigh	6.4	9.8	12.7	17.1	21.0	25.3
	Planlow	6.4	9.7	12.7	17.1	20.9	25.2
	Planlinear	6.4	9.8	12.7	17.1	21.0	25.3
	Planhigh	6.5	9.8	12.7	17.1	21.0	25.3
	RSlow	6.4	9.8	12.7	17.1	21.0	25.3
	Rslinear	6.5	9.8	12.7	17.1	21.0	25.3
	Rshigh	6.5	9.8	12.7	17.1	21.0	25.3

		Peak Discharge [m^3/s]					
		2-yr, 24-hr	5-yr, 24-hr	10-yr, 24-hr	25-yr, 24-hr	50-yr, 24-hr	100-yr, 24-hr
TrdA3b	**Initial Conditions**	6.1	9.8	13.2	18.5	23.1	28.3
	Baselow	6.4	10.2	13.7	19.1	23.8	29.0
	Baselinear	6.4	10.3	13.7	19.1	23.9	29.1
	Basehigh	6.5	10.4	13.9	19.4	24.2	29.4
	Planlow	6.4	10.3	13.7	19.1	23.9	29.1
	Planlinear	6.5	10.3	13.8	19.3	24.0	29.3
	Planhigh	6.6	10.5	14.0	19.5	24.3	29.6
	RSlow	6.5	10.4	13.9	19.3	24.1	29.3
	Rslinear	6.6	10.5	14.0	19.5	24.3	29.5
	Rshigh	6.6	10.5	14.0	19.5	24.3	29.6
TrdA4a	**Initial Conditions**	3.3	5.0	6.6	8.9	10.9	13.2
	Baselow	3.4	5.3	6.9	9.4	11.5	13.9
	Baselinear	3.4	5.3	6.9	9.4	11.5	13.9
	Basehigh	3.4	5.3	6.9	9.4	11.6	13.9
	Planlow	3.4	5.3	6.9	9.4	11.5	13.9
	Planlinear	3.4	5.3	6.9	9.4	11.5	13.9
	Planhigh	3.4	5.3	7.0	9.5	11.6	14.0
	RSlow	3.4	5.3	6.9	9.4	11.5	13.9
	Rslinear	3.4	5.3	7.0	9.4	11.6	13.9
	Rshigh	3.4	5.3	7.0	9.5	11.6	14.0
TrdA4b	**Initial Conditions**	3.1	5.1	6.8	9.5	11.9	14.5
	Baselow	3.2	5.2	7.0	9.7	12.1	14.7
	Baselinear	3.2	5.2	7.0	9.7	12.1	14.8
	Basehigh	3.3	5.3	7.1	9.8	12.2	14.8
	Planlow	3.2	5.2	7.0	9.7	12.1	14.7
	Planlinear	3.2	5.3	7.0	9.7	12.1	14.8
	Planhigh	3.3	5.3	7.1	9.8	12.2	14.9
	RSlow	3.2	5.2	7.0	9.7	12.1	14.7
	Rslinear	3.2	5.3	7.0	9.8	12.2	14.8
	Rshigh	3.3	5.3	7.0	9.8	12.2	14.8

Table 42. Predicted Peak Flow Changes from 2005 for the Tred Avon River Watersheds

		% Change from 2005 Peak Discharge					
		2-yr, 24-hr	5-yr, 24-hr	10-yr, 24-hr	25-yr, 24-hr	50-yr, 24-hr	100-yr, 24-hr
TrdA1	**Initial Conditions**	-	-	-	-	-	-
	Baselow	1.0%	0.9%	0.8%	0.7%	0.7%	0.6%
	Baselinear	1.2%	1.0%	0.9%	0.8%	0.8%	0.7%
	Basehigh	1.5%	1.3%	1.2%	1.0%	1.0%	0.9%
	Planlow	1.0%	0.9%	0.8%	0.7%	0.7%	0.6%
	Planlinear	1.2%	1.0%	0.9%	0.8%	0.8%	0.7%
	Planhigh	1.5%	1.3%	1.2%	1.0%	1.0%	0.9%
	RSlow	1.1%	1.0%	0.9%	0.8%	0.7%	0.7%
	Rslinear	1.3%	1.1%	1.0%	0.9%	0.8%	0.8%
	Rshigh	1.4%	1.2%	1.1%	1.0%	0.9%	0.8%
TrdA2	**Initial Conditions**	-	-	-	-	-	-
	Baselow	2.8%	2.4%	2.2%	1.9%	1.7%	1.6%
	Baselinear	3.2%	2.8%	2.5%	2.2%	2.0%	1.9%
	Basehigh	4.1%	3.5%	3.1%	2.8%	2.5%	2.3%
	Planlow	3.0%	2.6%	2.3%	2.1%	1.9%	1.7%
	Planlinear	3.5%	3.0%	2.7%	2.4%	2.2%	2.0%
	Planhigh	4.4%	3.7%	3.4%	3.0%	2.7%	2.5%
	RSlow	3.3%	2.9%	2.6%	2.3%	2.1%	1.9%
	Rslinear	3.8%	3.3%	3.0%	2.6%	2.4%	2.2%
	Rshigh	4.1%	3.6%	3.2%	2.8%	2.6%	2.4%
TrdA3a	**Initial Conditions**	-	-	-	-	-	-
	Baselow	-0.8%	-0.7%	-0.7%	-0.6%	-0.6%	-0.6%
	Baselinear	-0.6%	-0.6%	-0.6%	-0.5%	-0.5%	-0.5%
	Basehigh	-0.5%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%
	Planlow	-0.6%	-0.6%	-0.6%	-0.5%	-0.5%	-0.5%
	Planlinear	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%
	Planhigh	-0.2%	-0.2%	-0.3%	-0.3%	-0.3%	-0.3%
	RSlow	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%
	Rslinear	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
	Rshigh	-0.1%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%

		% Change from 2005 Peak Discharge					
		2-yr, 24-hr	5-yr, 24-hr	10-yr, 24-hr	25-yr, 24-hr	50-yr, 24-hr	100-yr, 24-hr
TrdA3b	**Initial Conditions**	-	-	-	-	-	-
	Baselow	4.7%	4.0%	3.6%	3.1%	2.8%	2.6%
	Baselinear	5.4%	4.6%	4.1%	3.6%	3.2%	3.0%
	Basehigh	7.3%	6.2%	5.5%	4.8%	4.4%	4.0%
	Planlow	5.4%	4.6%	4.1%	3.5%	3.2%	2.9%
	Planlinear	6.4%	5.4%	4.8%	4.2%	3.8%	3.4%
	Planhigh	8.3%	7.0%	6.2%	5.4%	4.9%	4.5%
	RSlow	6.7%	5.6%	5.0%	4.4%	4.0%	3.6%
	Rslinear	8.0%	6.7%	6.0%	5.2%	4.8%	4.3%
	Rshigh	8.5%	7.2%	6.4%	5.6%	5.0%	4.6%
TrdA4a	**Initial Conditions**	-	-	-	-	-	-
	Baselow	4.4%	4.9%	5.1%	5.2%	5.3%	5.3%
	Baselinear	4.7%	5.1%	5.3%	5.4%	5.5%	5.5%
	Basehigh	5.1%	5.6%	5.7%	5.8%	5.8%	5.8%
	Planlow	4.6%	5.1%	5.2%	5.4%	5.4%	5.4%
	Planlinear	5.0%	5.4%	5.6%	5.7%	5.7%	5.7%
	Planhigh	5.6%	5.9%	6.0%	6.1%	6.1%	6.0%
	RSlow	4.9%	5.4%	5.5%	5.6%	5.6%	5.6%
	Rslinear	5.4%	5.8%	5.9%	5.9%	5.9%	5.9%
	Rshigh	5.6%	6.0%	6.1%	6.1%	6.1%	6.0%
TrdA4b	**Initial Conditions**	-	-	-	-	-	-
	Baselow	2.9%	2.4%	2.2%	1.9%	1.7%	1.5%
	Baselinear	3.4%	2.8%	2.5%	2.2%	2.0%	1.8%
	Basehigh	4.3%	3.6%	3.2%	2.8%	2.5%	2.3%
	Planlow	3.0%	2.5%	2.2%	2.0%	1.8%	1.6%
	Planlinear	3.6%	3.0%	2.7%	2.3%	2.1%	1.9%
	Planhigh	4.7%	3.9%	3.5%	3.0%	2.7%	2.5%
	RSlow	3.3%	2.8%	2.5%	2.2%	1.9%	1.8%
	Rslinear	3.8%	3.1%	2.8%	2.4%	2.2%	2.0%
	Rshigh	4.2%	3.5%	3.1%	2.7%	2.5%	2.2%

Table 43. Predicted Peak Flows for the Wicomico River Watersheds

		Peak Discharge [m^3/s]					
		2-yr, 24-hr	**5-yr, 24-hr**	**10-yr, 24-hr**	**25-yr, 24-hr**	**50-yr, 24-hr**	**100-yr, 24-hr**
Wic1	**Initial Conditions**	42.6	70.2	96.6	139.0	177.7	223.3
	Baselow	44.0	72.1	98.9	142.0	181.3	227.4
	Baselinear	44.5	72.8	99.8	143.2	182.6	229.0
	Basehigh	44.7	73.1	100.2	143.7	183.3	229.7
	Planlow	44.1	72.2	99.1	142.2	181.6	227.7
	Planlinear	44.6	72.9	99.9	143.3	182.8	229.1
	Planhigh	44.8	73.3	100.4	143.9	183.5	230.0
	RSlow	44.2	72.4	99.3	142.5	181.8	228.0
	Rslinear	44.5	72.9	99.9	143.3	182.7	229.1
	Rshigh	44.7	73.1	100.2	143.6	183.1	229.6
Wic2	**Initial Conditions**	19.6	32.0	43.7	62.3	79.5	99.1
	Baselow	20.0	32.5	44.4	63.2	80.5	100.3
	Baselinear	20.2	32.9	44.8	63.7	81.1	101.0
	Basehigh	20.4	33.0	45.0	64.0	81.4	101.3
	Planlow	20.0	32.6	44.4	63.3	80.5	100.4
	Planlinear	20.3	32.9	44.8	63.7	81.1	101.0
	Planhigh	20.4	33.1	45.0	64.0	81.4	101.4
	RSlow	20.1	32.7	44.5	63.4	80.7	100.5
	Rslinear	20.3	32.9	44.8	63.8	81.2	101.1
	Rshigh	20.4	33.0	45.0	64.0	81.4	101.3
Wic3	**Initial Conditions**	3.9	6.6	9.1	13.2	16.9	21.1
	Baselow	4.0	6.7	9.2	13.3	17.1	21.4
	Baselinear	4.1	6.8	9.4	13.5	17.3	21.6
	Basehigh	4.1	6.8	9.5	13.6	17.4	21.7
	Planlow	4.0	6.7	9.3	13.4	17.2	21.4
	Planlinear	4.1	6.8	9.4	13.6	17.3	21.6
	Planhigh	4.1	6.9	9.5	13.7	17.5	21.8
	RSlow	4.1	6.7	9.3	13.5	17.2	21.5
	Rslinear	4.1	6.8	9.4	13.6	17.4	21.7
	Rshigh	4.1	6.9	9.5	13.7	17.5	21.8

		Peak Discharge [m^3/s]					
		2-yr, 24-hr	5-yr, 24-hr	10-yr, 24-hr	25-yr, 24-hr	50-yr, 24-hr	100-yr, 24-hr
Wic4	**Initial Conditions**	0.9	1.5	2.2	3.2	4.2	5.3
	Baselow	0.9	1.6	2.3	3.3	4.3	5.5
	Baselinear	0.9	1.6	2.3	3.4	4.3	5.5
	Basehigh	0.9	1.6	2.3	3.4	4.4	5.5
	Planlow	0.9	1.6	2.3	3.3	4.3	5.5
	Planlinear	0.9	1.6	2.3	3.4	4.4	5.5
	Planhigh	0.9	1.6	2.3	3.4	4.4	5.5
	RSlow	0.9	1.6	2.3	3.4	4.4	5.5
	Rslinear	0.9	1.6	2.3	3.4	4.4	5.5
	Rshigh	1.0	1.6	2.3	3.4	4.4	5.5

Table 44. Predicted Peak Flow Changes from 2005 for the Wicomico River Watersheds

		% Change from 2005 Peak Discharge					
		2-yr, 24-hr	5-yr, 24-hr	10-yr, 24-hr	25-yr, 24-hr	50-yr, 24-hr	100-yr, 24-hr
Wic1	**Initial Conditions**	-	-	-	-	-	-
	Baselow	3.2%	2.7%	2.4%	2.2%	2.0%	1.9%
	Baselinear	4.4%	3.7%	3.4%	3.0%	2.8%	2.6%
	Basehigh	4.9%	4.2%	3.8%	3.4%	3.1%	2.9%
	Planlow	3.4%	2.9%	2.6%	2.3%	2.1%	2.0%
	Planlinear	4.5%	3.8%	3.4%	3.1%	2.8%	2.6%
	Planhigh	5.2%	4.4%	4.0%	3.5%	3.2%	3.0%
	RSlow	3.6%	3.1%	2.8%	2.5%	2.3%	2.1%
	Rslinear	4.5%	3.8%	3.4%	3.0%	2.8%	2.6%
	Rshigh	4.8%	4.1%	3.7%	3.3%	3.0%	2.8%

		% Change from 2005 Peak Discharge					
		2-yr, 24-hr	5-yr, 24-hr	10-yr, 24-hr	25-yr, 24-hr	50-yr, 24-hr	100-yr, 24-hr
Wic2	**Initial Conditions**	-	-	-	-	-	-
	Baselow	2.0%	1.7%	1.6%	1.4%	1.3%	1.2%
	Baselinear	3.3%	2.8%	2.5%	2.2%	2.1%	1.9%
	Basehigh	3.9%	3.3%	3.0%	2.6%	2.4%	2.2%
	Planlow	2.2%	1.9%	1.7%	1.5%	1.4%	1.3%
	Planlinear	3.4%	2.9%	2.6%	2.3%	2.1%	1.9%
	Planhigh	4.0%	3.4%	3.1%	2.7%	2.5%	2.3%
	RSlow	2.5%	2.2%	1.9%	1.7%	1.6%	1.5%
	Rslinear	3.5%	3.0%	2.7%	2.3%	2.2%	2.0%
	Rshigh	3.9%	3.3%	3.0%	2.6%	2.4%	2.2%
Wic3	**Initial Conditions**	-	-	-	-	-	-
	Baselow	1.8%	1.5%	1.4%	1.2%	1.1%	1.0%
	Baselinear	3.8%	3.2%	2.9%	2.5%	2.3%	2.1%
	Basehigh	4.8%	4.1%	3.7%	3.2%	2.9%	2.7%
	Planlow	2.5%	2.1%	1.9%	1.6%	1.5%	1.4%
	Planlinear	4.2%	3.6%	3.2%	2.8%	2.6%	2.3%
	Planhigh	5.4%	4.5%	4.1%	3.6%	3.3%	3.0%
	RSlow	3.1%	2.7%	2.4%	2.1%	1.9%	1.8%
	Rslinear	4.5%	3.9%	3.4%	3.0%	2.8%	2.5%
	Rshigh	5.4%	4.6%	4.1%	3.6%	3.3%	3.0%
Wic4	**Initial Conditions**	-	-	-	-	-	-
	Baselow	5.7%	4.8%	4.3%	3.7%	3.3%	3.1%
	Baselinear	6.2%	5.2%	4.7%	4.1%	3.7%	3.4%
	Basehigh	6.7%	5.6%	5.0%	4.3%	3.9%	3.6%
	Planlow	6.1%	5.1%	4.6%	4.0%	3.6%	3.3%
	Planlinear	7.1%	6.0%	5.4%	4.7%	4.2%	3.8%
	Planhigh	7.6%	6.4%	5.7%	5.0%	4.5%	4.1%
	RSlow	7.0%	5.9%	5.2%	4.6%	4.1%	3.8%
	Rslinear	7.7%	6.4%	5.8%	5.0%	4.5%	4.1%
	Rshigh	8.6%	7.3%	6.5%	5.6%	5.1%	4.6%

Appendix G. Values used in Plots of Realization Variability for the Wicomico Watersheds

Table 45. Variability between SLEUTH Realizations for the Wicomico River Watersheds

	Watershed	Area [sq. km]	Q1	Median	Q3	Q3-Q1
100-yr, 24-hr Discharge/Mean Base Linear Discharge	Wic 1	250.5	0.9998	1.00000	1.0002	0.0004
	Wic 2	81.6	0.9997	1.00000	1.0003	0.0006
	Wic 3	11.9	0.9995	0.99980	1.0011	0.0016
	Wic 4	2.6	0.9989	1.00020	1.0011	0.0022
2-yr, 24-hr Discharge/ Mean Base Linear Discharge	Wic 1	250.5	0.9996	1.00000	1.0004	0.0008
	Wic 2	81.6	0.9995	1.00000	1.0006	0.0011
	Wic 3	11.9	0.9991	1.00000	1.0016	0.0025
	Wic 4	2.6	0.9976	1.00060	1.0014	0.0038
Sediment Load/ Mean Base Linear Sediment Load	Wic 1	250.5	0.9992	0.99980	1.0008	0.0016
	Wic 2	81.6	0.9994	0.99990	1.0008	0.0014
	Wic 3	11.9	0.9965	1.00000	1.006	0.0095
	Wic 4	2.6	0.9804	0.99390	1.0161	0.0357
Phosphorus Load/ Mean Base Linear Phosphorus Load	Wic 1	250.5	0.9996	1.0001	1.0002	0.0006
	Wic 2	81.6	0.9997	1.00000	1.0004	0.0007
	Wic 3	11.9	0.9988	0.99980	1.0023	0.0035
	Wic 4	2.6	0.9957	0.99880	1.0027	0.007
Nitrogen Load/ Mean Base Linear Nitrogen Load	Wic 1	250.5	0.9996	1.0001	1.0002	0.0006
	Wic 2	81.6	0.9998	1.0001	1.0002	0.0004
	Wic 3	11.9	0.9989	0.9998	1.0022	0.0033
	Wic 4	2.6	0.9958	0.9989	1.0026	0.0068